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# EFFECT OF INITIAL WEIGHT, RANGE-FEEDING AND FATTENING ON GAIN AND EDIBLE PORTION IN BARRED PLYMOUTH ROCK COCKERELS[1]

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In the production of high-grade market poultry of varying weights it is necessary to determine the relative meat values of carcasses produced under different methods of management during growth.

The relative value of fattening chickens at different stages of growth or at different weights during growth, as regards the possible live-weight gains and the quality of the meat carcasses produced, in comparison to the gains to be made with similar stock fed on range and their meat values is an economic problem worthy of attention. Since dressed poultry is graded according to degree of fleshing and fatness, the value of the fattening period in producing the higher grade carcass is of importance to the producer.

The development of muscle and fat in the body increases with increasing age or weight. Such being the case, the more nearly mature the individual is when fattened, the greater is the possibility of getting a high-grade carcass. Range-grown stock generally develop heavier muscling than do confinement-grown stock. The type of stock handled, however, may vary somewhat in ultimate size and weight; hence weight alone is not a criterion of body maturity.

Mitchell, Card and Hamilton (3 and 4) have shown the relative increase in weight of parts of carcasses with increase in body weight in White Plymouth Rock and White Leghorn stock respectively during the growth period. With the White Plymouth Rock cockerel stock ranging in weight from .5 pound to 7 pounds, the empty weight of the 7-pound group increases to 14.73 times the empty weight of the .5-pound group, the total offal increases 13.67 times, the total viscera 6.77 times, and the total dressed carcass 18.88 times. The bones in the carcass increase in weight 13.08 times, while the total flesh and fat increase 27.09 times. Prentice and Baskett (8) state that where a good rearing ration is fed to young stock on range the live-weight gains are equal to, or better than, those made in a similar period of time with similar stock confined in the fattening crates and fed a soft mash. The only differences found were in the colour and texture of the skin.

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Maw (1) and Jull and Maw (5) have shown that the size or live weight of a chicken, when placed in the fattening crate, determines the length of feeding period which will give the most economical gains when fed three times daily on full-feeding. Jull and Maw (6) have also shown the differences in the percentage of edible flesh and fat on the carcasses of unfattened and fattened broilers and roasters; the unfattened broilers showing 54.27% as contrasted to 60.73% in the fattened broilers, with roasters the unfattened group showed 56.86% as compared to 63.07% with the fattened roasters.

Harshaw (7) found the total edible portion in range-fed stock to average from 6 to 8% higher than that in confined crate-fed stock of similar age.

Maw (2) reported the relative effect of fattening on the percentage of the chilled dressed weight in relation to the initial weight with varying sizes of stock. Birds with an initial weight of 2 and 3 pounds dressed 109 and 104% respectively, whereas birds weighing 4, 5 and 6 pounds dressed only 97, 94 and 95% respectively.

## MATERIAL AND METHODS

A group of 127 Barred Plymouth Rock cockerels, which had been brooded in batteries for 10 weeks, was placed on range in open range shelters. Bi-weekly body weight and feed consumption records were kept throughout the growing season. Similar records were kept during the first 10 weeks, with the exception that the feed record represented the average for cockerels and pullets combined. All birds were weighed individually before feeding in the morning.

The problem was to determine the differences between cockerels in different stages of growth, as classed by approximate even-pound weights, in their ability to make economic gains as meat stock during the fattening process. As the average starved live weights of 2, 3, 4, 5 and 6 pounds were attained, a group of 25 representative individuals was selected. Ten individuals were marked and left on the range for a 14-day growing period, during which time a second group of 10 individuals was individually crate-fattened. The other 5 individuals were killed and dressed immediately to be used as control stock in the determination of the relative increase in body weight, as well as in edible portion and waste in the dressed carcass during the 14-day period, based on the initial approximate even-pound weight. At the end of the 14 days, 5 of the range-fed individuals and the 10 fattened individuals were killed, dressed and boned.

*Method of Feeding*

The stock on the range was hopper-fed with a ration of mixed scratch grain, composed of cracked yellow corn, whole wheat, barley, and oats, and a developing mash carrying 17% protein. The stock was housed in an open range shelter.

The stock to be fattened was confined to individual fattening crates indoors. The ration fed was as follows: yellow cornmeal 30 lbs., hull-less oatmeal 30 lbs., white wheat middlings 27.5 lbs., beef meal 7.5 lbs., powdered skimmilk 5 lbs., and salt 1 lb. The feed was mixed with twice

its dry weight in water, giving a consistency which poured freely from a pail. The stock was full-fed 3 times daily—morning, noon, and evening—allowing about 30 minutes for feeding, after which the troughs were scraped clean. Full-feeding was practised from the first feed throughout the period of 14 days. Individual gains in weight and feed consumption were recorded at the 7-and 14-day periods.

*Dressing*

After a period of about 18 hours for starving, the two groups of stock, range and fattened, were killed and dressed, recording blood and feather losses. Dressed weights were taken immediately after dressing and again after 24 hours in cold storage. The individuals were then drawn and boned for determination of the edible and non-edible parts.

## RESULTS

Table 1 presents the initial weight, gain and feed consumption of the two groups. The initial weights of the contrasted groups were quite close, except in the case of the 2-pound class. In all cases better gains were made by the confined birds than those kept on free range. However, only in the case of the 2-, 3- and 6-pound groups were the gains significantly better. These differences suggest that there may be a time in the growth of the chicken when confined fattening results in an increase in weight no greater than that made by birds on range. The birds at the 4- and 5- pound stage were apparently in a period of rapid growth which equalled the increase produced by confinement and a fattening ration.

TABLE 1.—INITIAL WEIGHT, GAIN AND FEED CONSUMPTION OF RANGE-FED BIRDS AND FATTENED BIRDS AT APPROXIMATE EVEN-POUND WEIGHTS (FATTENED 14 DAYS)

| | Group | Initial weight (grams) | Gain (grams) | Feed consumption (grams) | Difference in gain (grams) |
|---|---|---|---|---|---|
| 2 lbs. | Range | 913.5±25.43 | 246.0±31.49 | — | 92.0±38.14 |
| | Fattened | 823.5±19.29 | 338.0±21.54 | 1301.6±62.21 | |
| 3 lbs. | Range | 1361.5± 9.66 | 192.0±36.24 | — | 123.0±48.83 |
| | Fattened | 1339.5±13.67 | 315.0±32.75 | 1618.4±62.11 | |
| 4 lbs. | Range | 1831.5±15.65 | 280.0±26.68 | — | 1.0±61.77 |
| | Fattened | 1854.0±14.33 | 281.0±55.73 | 1656.7±73.59 | |
| 5 lbs. | Range | 2316.5±25.95 | 246.0±38.61 | — | 13.0±50.90 |
| | Fattened | 2326.0±35.75 | 257.0±33.19 | 1886.9±58.50 | |
| 6 lbs. | Range | 2698.5±27.48 | 201.5±35.87 | — | 98.5±48.29 |
| | Fattened | 2680.5±31.02 | 300.0±32.35 | 1921.8±47.02 | |

TABLE 2.—RELATIVE INCREASE IN LIVE WEIGHT, EDIBLE PORTION AND WASTE OF RANGE-FED BIRDS AND FATTENED BIRDS (EXPRESSED IN PERCENTAGE)

| — | No. of birds | Approximate weight | | | | |
|---|---|---|---|---|---|---|
| | | 2 lbs. | 3 lbs. | 4 lbs. | 5 lbs. | 6 lbs. |
| Live weight— | | | | | | |
| Range (initial weight) | 10 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| (final weight) | | 126.9 | 114.1 | 115.2 | 110.6 | 107.4 |
| Fattened (initial weight) | 10 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| (final weight) | | 141.6 | 123.5 | 115.1 | 111.9 | 111.1 |
| Chilled dressed weight— | | | | | | |
| Control group | 5 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Range (14 days) | 5 | 141.9 | 109.5 | 111.6 | 114.3 | 107.1 |
| Fattened (14 days) | 10 | 130.1 | 123.7 | 112.7 | 111.3 | 111.1 |
| Edible portion— (flesh, skin and fat; heart, liver, and gizzard) | | | | | | |
| Control group | 5 | 37.5 | 40.7 | 40.7 | 46.2 | 47.4 |
| Range (14 days) | 5 | 39.4 | 37.8 | 46.8 | 46.9 | 49.9 |
| Fattened (14 days) | 10 | 38.7 | 43.5 | 46.4 | 48.7 | 50.2 |
| Waste (of chilled dressed weight; head, feet and shanks, and entrails) | | | | | | |
| Control group | 5 | 39.0 | 35.9 | 32.4 | 31.0 | 31.5 |
| Range (14 days) | 5 | 37.6 | 34.3 | 32.9 | 31.8 | 30.0 |
| Fattened (14 days) | 10 | 34.7 | 31.8 | 32.9 | 31.7 | 30.1 |

In Table 2 the live weight and chilled dressed weight changes of the range and fattened groups have been expressed in per cent, using the initial weights as 100%. The edible portion and waste are also given in percentage of the total chilled dressed weight. The percentage of edible flesh of the control group increased with the increased live weight. Comparing the control, range and fattened groups for any one weight class, it can be seen that, in the lower weights, the percentage of edible flesh varied considerably. Only in the 5- and 6-pound class was the percentage of edible flesh increased by 14 days on range or by fattening. The fattened group had a higher percentage of edible flesh than the control group for all weight classes. No definite differences were found between the groups in the amount of waste resulting from the drawing of the carcasses.

## CONCLUSIONS

The live weight gain of a chicken during the fattening period and the percentage of edible flesh is related to the initial weight or stage of body development when placed in the fattening crate. Smaller birds made relatively higher gains in weight with smaller quantities of feed consumed per pound gain.

The birds in the 4- and 5-pound weight class did not gain appreciably more when fattened than birds of similar weight left on range for the same period of time.

## REFERENCES

1. MAW, W. A. Experimental fattening results. A.A.I.I.P.H. 7, 6 : 4-48. 1921.

2. MAW, W. A. Poultry production facts with special reference to quality meat production. Proc. Northeastern Poultry Producers' Council, pp. 39-46. 1938.

3. MITCHELL, H. H., CARD, L. E. and HAMILTON, T. S. The growth of White Plymouth Rock chickens. Illinois Agr. Exp. Sta. Bull. 278 : 71-132. 1926.

4. MITCHELL, H. H., CARD, L. E. and HAMILTON, T. S. A technical study of the growth of White Leghorn chickens. Illinois Agr. Exp. Sta. Bull. 367. 1931.

5. JULL, M. A. and MAW, W. A. Experimental fattening results. Poul. Sci. 2, 4 : 99-111. 1923.

6. JULL, M. A. and MAW, W. A. Determination of the dressed, drawn and edible percentages of various kinds of dressed fowl. Sci. Agri. 3, 10 : 329. 1923.

7. HARSHAW, H. M. Effect of diet, range, and fattening on the physical and chemical composition of cockerels. Jour. Agric. Res. 53, 5 : 357-368. 1936.

8. PRENTICE, J. H. and BASKETT, R. G. Notes on the fattening of surplus cockerels. Jour. Min. of Agr., North Ireland. 1932.

# PATHOGENICITY TESTS WITH CULTURES OF *OPHIOBOLUS GRAMINIS* SACC.[1]

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Previous work, by Davis (2), Moritz (6), Krebs (4), Russell (8), Padwick (7) and Hynes (3), has shown that different isolates of *Ophiobolus graminis* Sacc. may vary considerably in their pathogenicity to any particular host. Padwick (7) refers to such isolates as "strains". He found that isolates which were strongly pathogenic to one host were strongly pathogenic to all others tested and, conversely, those which were only slightly pathogenic to one host were not strongly pathogenic to any others. Therefore his strains could not be differentiated by their selective pathogenicity to a group of differential hosts, as is the case with physiologic forms of stem rust, *Puccinia graminis* Pers. Van de Laar (5) discovered physiologic forms of *Ophiobolus herpotrichus* (Fr.) Sacc. but not of *O. graminis*. On the other hand, Hynes (3) reported finding six physiologic forms, distinguished by cultural characteristics, which gave a differential reaction when tested on several varieties of cereals. While the author has occasionally noticed differences in the cultural characteristics of his isolates, his experiments on this phase of the take-all problem have dealt only with the differences in pathogenicity, to wheat, which they possessed.

Not only do different isolates vary in the degree of their pathogenic vigour, but the author (8) has reported that the pathogenicity of certain isolates fluctuated from time to time, although the general tendency was for them to become weaker with increased time in artificial culture. It is the purpose of this paper to report the results of further tests on the relative pathogenicity of the eight isolates dealt with previously, together with the results of similar tests with other isolates and special cultures.

## FURTHER TESTS WITH THE ORIGINAL EIGHT ISOLATES

Previous work with these isolates of *O. graminis* was reported in 1934 (8). The technique employed in testing the pathogenicity of the isolates and the method for computing the disease rating is described in detail in the same bulletin (p. 25). One of these isolates came from Australia, two from the United States and five of them were isolated by the author from material collected in Saskatchewan. The isolates were maintained in pure culture on potato dextrose agar and kept in a refrigerator at a temperature of about 12° C. The Saskatchewan isolates have now been growing in artificial culture for periods ranging from 9 years in the case of Isolate 6 to 14 years in the case of Isolate 1, while Isolate 31 from Australia and Isolates 10 and 11 from the United States have probably been in pure

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culture for 15 years or more. Whenever it was desired to compare their pathogenicity, additional cultures were prepared, either on potato dextrose agar or ground oat-hulls, and this was used as inoculum to infect wheat

FIGURE 1. Development of wheat seedlings at the end of the pathogenicity test made in December, 1938. Left to right; check, disease rate 4, dry weight 1.999 grams; inoculated with isolate 2, disease rate 17, dry weight 1.776 grams; inoculated with isolate 10, disease rate 51, dry weight 1.172 grams; and inoculated with isolate 6, disease rate 96 per cent, dry weight 0.416 grams.

seedlings growing in sterilized soil in glazed earthenware crocks in the greenhouse. When agar inoculum was used a small disc of the culture was placed on each seed as it was sown. In this way each seedling was exposed

to approximately the same amount of the pathogen and very little extraneous material was added to the soil. Moisture conditions were kept fairly uniform throughout all the crocks in any one experiment by placing equal amounts of soil and water in each crock and by bringing them up to the proper weight whenever water was added during the course of the experiment. A disease rating based on the amount of stunting and lesions produced gave a good measure of the severity of the infection (Figure 1).

Table 1 shows the disease rates produced by each isolate in these tests. Figure 1 shows some of the seedlings from the December, 1938, test, and Figure 2 illustrates graphically the manner in which the pathogenicity of three of the isolates has fluctuated during the past 9 years. It may be seen from an examination of Table 1 and Figure 2 that the disease rates secured in these tests have fluctuated from time to time independently of the environmental conditions obtaining at the time of each test.

TABLE 1.—DISEASE RATES OBTAINED BY INOCULATING MARQUIS WHEAT AT SEEDING TIME WITH DIFFERENT ISOLATES OF *O. graminis*

| Date of test | Isolate number | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 6 | 10 | 11 | 31 | Check | 7a |
| April, 1934 | 46 | 95 | 12 | 78 | 23 | – | – | – | 7 | – |
| October, 1937 | 24 | 45 | 6 | 10 | 49 | 6 | 27 | 15 | 8 | – |
| December, 1938 | 30 | 17 | 14 | 9 | 96 | 51 | 37 | 16 | 8 | 91 |
| January, 1939 | 32 | 35 | 12 | 12 | 62 | 17 | 19 | 23 | 12 | 93 |
| March, 1939 | 47 | 46 | 24 | 23 | 49 | 35 | 46 | 47 | 10 | 71 |

In a previous report (8) these eight isolates were placed in three different classes according to the average of the disease rates which they had produced previous to 1934. Isolates 2, 4 and 6 were strongly pathogenic, *i.e.*, their average disease rates were over 65%. Isolates 1, 10 and 11 were moderately pathogenic having average disease rates falling between 35 and 64%. Isolates 3 and 31 were only slightly pathogenic, as the disease rates which they produced averaged less than 35%. (Fig. 2).

Since 1934 the pathogenicity of most of the isolates has continued to fluctuate (Table 1). For instance the pathogenicity of Isolate 1 was moderate when tested in 1934, slight at the time of the next three tests, and it is now moderate again. The pathogenicity of Isolate 2, during the same period, dropped from severe to slight and rose to moderate again. The pathogenicity of Isolate 3 remained slight while that of Isolate 4 dropped from severe to slight, and has not yet recovered much of its former pathogenicity. Isolate 6 behaved in the opposite manner to Isolate 1, *i.e.*, it was slightly pathogenic in 1934, moderately pathogenic in 1937, severely pathogenic in 1938 and now it is moderately so. Isolates 10, 11 and 31 also fluctuated in respect to their pathogenicity, but they are all moderately pathogenic at the present time in spite of the fact that they have been cultured artificially for over 15 years. Isolate 7a, included for comparison, is a fresh culture isolated in the autumn of 1938.

## THE RELATIVE PATHOGENICITY OF FIVE SINGLE-SPORE CULTURES OF ISOLATE 3 OF *O. GRAMINIS*

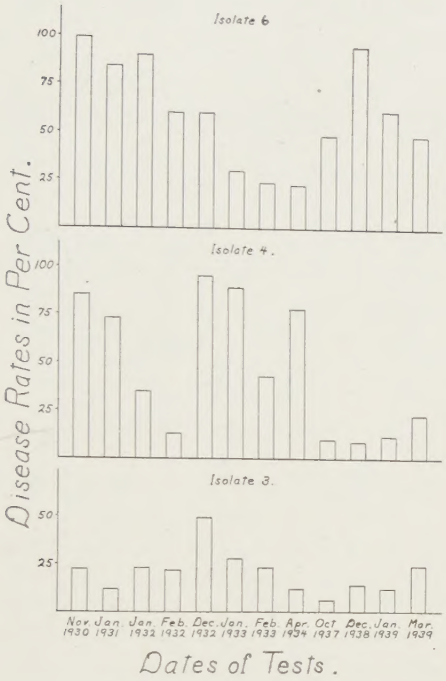


FIGURE 2. Fluctuations in pathogenicity shown by three isolates of *O. graminis* over a period of nine years. The disease rates, produced by the different isolates on wheat, rose and fell independently, showing that some influence besides environmental factors were partly responsible for the fluctuations.

Five single spore cultures were obtained from two perithecia found on wheat stubble collected at Cudworth, Sask., in August, 1928. For a number of years these were maintained in pure culture but only one of them was used in pathogenicity tests. It was consistently weak (8, p. 35). Finally, all of these single-spore isolates were tested to see if any of them were more pathogenic than the one which had been used previously. The test was repeated twice, and in two of the tests Isolate 4 was included for purposes of comparison. The results of these tests are summarized in Table 2.

The above results show that there was some variation in the pathogenicity of the different single-spore cultures of Isolate 3 but, compared with Isolate 4, they were all weakly pathogenic.

TABLE 2.—DISEASE RATES OBTAINED BY INOCULATING MARQUIS WHEAT AT SEEDING TIME WITH DIFFERENT SINGLE-SPORE CULTURES OF ISOLATES 3 AND 4

| Date of test | Isolate number | | | | | | | Average of 3a–3e |
|---|---|---|---|---|---|---|---|---|
| | Check | 3a | 3b | 3c | 3d | 3e | 4 | |
| January, 1936 | 8 | 5 | 19 | 7 | 10 | 18 | 75 | 12 |
| February, 1936 | 2 | 8 | 9 | 5 | 7 | 16 | — | 9 |
| March, 1936 | 12 | 11 | 17 | 9 | 11 | 15 | 80 | 13 |
| Average | 7 | 8 | 15 | 7 | 9 | 16 | 77 | |

## THE RELATIVE PATHOGENICITY OF NINE CULTURES OF ISOLATE 8

In the autumn of 1938 a number of cultures were isolated from wheat stubble bearing *O. graminis* from two different fields in the Quill Lake district. The silver nitrate method, recommended by Davies (1) was

used in making these isolations. Nine cultures were obtained, arising from as many different fragments of diseased host material from one field. These were compared as to pathogenicity in three separate tests with the results shown in Table 3.

TABLE 3.—DISEASE RATES OBTAINED BY INOCULATING MARQUIS WHEAT AT SEEDING TIME WITH DIFFERENT CULTURES OF ISOLATE 8

| Date of test | Isolate number | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Check | 8a | 8b | 8c | 8d | 8e | 8f | 8g | 8h | 8i | Ave. |
| February, 1939 | 5 | 56 | 46 | 55 | 62 | 59 | 52 | 48 | 58 | 65 | 55 |
| March, 1939 | 8 | 30 | 34 | 44 | 42 | 29 | 32 | 30 | 47 | 40 | 36 |
| April, 1939 | 11 | 12 | 10 | 18 | 16 | 17 | 21 | 19 | 20 | 11 | 16 |
| Average | 8 | 33 | 30 | 39 | 40 | 35 | 35 | 32 | 42 | 39 | |

The disease rates, obtained from the different cultures in these tests, are not widely different and it seems probable that they all belong to the same strain of *O. graminis*. The results show a distinct decline in disease rate with the approach of spring. This has been noted before in our work with other isolates of this fungus. Possibly it may be ascribed partly to increased vigour of the host with improved light intensity. Also it may be attributed, in part, to more active antagonistic action of the soil microflora re-entering the sterilized soil, because the temperature in the greenhouse tends to average higher as the intensity and duration of the sunlight increases.

## THE INFLUENCE OF CERTAIN ENVIRONMENTAL CONDITIONS ON THE PATHOGENICITY OF ISOLATES 2 AND 4 OF *O. GRAMINIS*

In an attempt to get some clue as to the cause of the fluctuations in pathogenicity of certain isolates of *O. graminis*, the following work was done. Starting in the autumn of 1933, subcultures of Isolates 2 and 4 were treated in three different ways. One culture of each isolate was kept on potato-dextrose agar in a refrigerator at a temperature of about 12° C. Another culture of each isolate was kept on the same medium in an incubator at a temperature of 24.5° C. A third culture of each isolate was repeatedly inoculated into, and reisolated from, wheat seedlings grown under aseptic conditions on plant nutrient agar in glass culture tubes. In the intervals between growth in the host the third culture of each isolate was kept on potato dextrose agar in the incubator. By 1938 these last mentioned cultures had been reisolated from wheat seedlings 13 times.

Two or three times each year the six cultures described above were tested on wheat seedlings grown in sterilized soil in crocks in the greenhouse and a disease rating was computed by the method previously described (8, p. 25). Data are given in Table 4 summarizing the results of these tests.

TABLE 4.—VARIATIONS IN PATHOGENICITY AS EXPRESSED BY DISEASE RATES OF SUBCULTURES OF ISOLATES 2 AND 4 WHEN GROWN AT TWO DIFFERENT TEMPERATURES AND WHEN REPEATEDLY PASSED THROUGH THE HOST.

| Date of test | Check | Isolate 2 | | | Isolate 4 | | | Average |
|---|---|---|---|---|---|---|---|---|
| | | 12° | 24° | Repeatedly reisolated | 12° | 24° | Repeatedly reisolated | |
| October, 1933 | 2.0 | 97.0 | 98.0 | — | 98.0 | 99.5 | — | 98.0 |
| April, 1934 | 5.0 | 67.0 | 63.0 | 54.5 | 54.5 | 51.0 | 44.0 | 55.0 |
| February, 1935 | 4.0 | 54.5 | 27.5 | 31.0 | — | 48.0 | 48.5 | 42.0 |
| March 20, 1935 | 8.5 | 31.0 | 21.0 | — | 40.0 | 26.0 | — | 29.5 |
| April, 1935 | 5.5 | — | — | — | — | 53.0 | — | — |
| November, 1935 | 11.5 | 74.5 | 47.5 | 34.0 | 78.5 | 76.5 | 49.0 | 60.0 |
| February, 1936 | — | 83.5 | 76.0 | 69.5 | 78.5 | 70.0 | 55.5 | 72.0 |
| March, 1936 | 11.5 | 65.5 | 36.0 | 40.0 | 73.0 | 61.0 | 35.0 | 51.5 |
| November, 1936 | 5.0 | 83.0 | 43.0 | 62.5 | 10.5 | 81.0 | 85.5 | 61.0 |
| March, 1937 | 12.0 | 29.0 | 32.5 | 34.5 | 12.0 | 18.5 | 38.0 | 27.5 |
| October, 1937 | 10.5 | 45.0 | 60.0 | 66.0 | 10.5 | 9.0 | 20.5 | 35.0 |
| November, 1937 | 5.5 | 61.0 | 53.0 | 50.0 | 9.5 | 13.0 | 64.5 | 40.0 |
| February, 1938 | 12.0 | 40.0 | 48.0 | 35.0 | 13.5 | 14.5 | 21.5 | 28.5 |
| October, 1938 | 11.0 | 55.5 | 46.5 | 47.5 | 5.5 | 7.5 | 16.5 | 30.0 |
| Average of all tests | 8.0 | 60.5 | 50.0 | 47.5 | 40.5 | 45.0 | 43.5 | |

As in previous tests reported by the author (8) Isolate 2 gave a higher disease rate on the average than did Isolate 4, but it may be seen from the data presented that neither differences in temperature, nor repeated passing through the host, produced any consistent effect on the pathogenicity of these two isolates. At the beginning of these tests all cultures of both isolates were strongly pathogenic. The culture of Isolate 2 maintained at 12° C. fluctuated considerably in pathogenicity; on the average it was moderately pathogenic, and it was still so at the close of the experiment. The other two cultures of Isolate 2 behaved in a similar manner, except that on the average they gave lower disease rates than the one kept at 12° C. The cultures of Isolate 4 fluctuated in the same manner but they lost their pathogenicity at different times toward the close of the experiment. The culture kept at 12° C. has not been more than slightly pathogenic since November, 1936; the one kept at 24° C. has shown only slight pathogenicity since March, 1937; and the one which has been repeatedly reisolated from wheat seedlings has been only slightly pathogenic since November, 1937. Still they continue to cause slight lesions to appear on some of the host roots.

## DISCUSSION

The results of the experiments just described throw some additional light on the pathogenic capabilities of isolates of *O. graminis* Sacc. which have been grown in artificial culture for long periods of time. In the majority of cases the isolates secured in Saskatchewan have proven highly pathogenic when first isolated. In the autumn of 1938 Isolate 2 gave a disease rate of about 45, while in the same test the newly isolated 7a, 7b, and 7c all gave disease rates of around 80, and 8a gave a disease rate of about 70. Isolate 3 is a notable exception to this, as it has always been

only slightly pathogenic to wheat. Of the imported ones, Isolate 10 is the only one which was highly pathogenic when we received it, and since then its pathogenicity has dropped to a very low level. At the present time, however, it is moderately pathogenic again. It seems possible that this loss of pathogenicity after long periods passed in pure culture may be attributable to the lack of traces of certain elements met with in nature but lacking in artificial culture; or it may result from the lack of any regular opportunity to form fruiting bodies such as occurs under natural conditions.

It is a matter of interest to know that all five single spore cultures of Isolate 3 were only slightly pathogenic to wheat compared with a strongly pathogenic culture such as Isolate 4. The possibility remains, of course, that one might find great variations in pathogenicity when working with single spore cultures of some other isolate of *O. graminis*. However, the different cultures of Isolate 8, derived from different fragments of diseased host material collected in a single field, all possessed about the same degree of pathogenicity.

The results presented in the third section of this paper proved somewhat surprising to the author. It was thought, when the work was being planned, that repeated passage through the host might have a tendency to maintain the pathogenicity of the fungus at a constant level or even to increase it. In each case, however, the average disease rate produced by these cultures was less than that produced by the cultures of the same isolate kept continuously on potato dextrose agar, although at the conclusion of the experiment they compared favourably with the ones which had not been repeatedly reisolated from the host. Perhaps the outstanding feature of these results is the remarkable falling off in pathogenicity of all the cultures of Isolate 4 since 1936, regardless of the fact that they were kept entirely separate and under different environmental conditions. It appears from these results that the loss in pathogenicity, which various cultures of *O. graminis* have shown after long periods in artificial culture, is caused by some factor which, under the conditions of the tests, works independently of temperature conditions and is unaffected by passing the culture repeatedly through the host plant.

## SUMMARY

1. The results of pathogenicity tests with numerous isolates and subcultures of *O. graminis* is reported.

2. While the pathogenicity of all isolates was found to fluctuate markedly with varying environmental conditions, it appears that the pathogenicity of each isolate may fluctuate independently so that for a period of time it may be relatively high and then for a period of time it may be relatively low.

3. The general observation, that the pathogenicity of all isolates tends to decrease with continued artificial culture, is qualified by the fact that some of these isolates have shown relatively high pathogenicity after a long period of relatively low pathogenicity.

4. An attempt was made to alter the pathogenicity of two isolates by maintaining subcultures at widely different temperatures and by repeatedly passing one subculture of each through the host. This was continued for a period of five years but the different treatments had no consistent effects on the pathogenicity of the cultures used.

## REFERENCES

1. Davies, F. R. Superiority of silver nitrate over mercuric chloride for surface sterilization in the isolation of *Ophiobolus graminis*. Can. J. Research 13 : 168-173. 1935.

2. Davis, R. J. Studies on *Ophiobolus graminis* Sacc. and the take-all disease of wheat. Jour. Agr. Research 31 : 9 : 801-825. 1925.

3. Hynes, H. J. Studies on "Take-all" of wheat—I. Jour. Austral. Inst. of Agric. Science, 3 : 1 : 43-48. 1937.

4. Krebs, J. Der Einfluss der Bodentemperature auf die Infektion von Weizenkeimlingen durch *Ophiobolus graminis* Sacc., dem Erreger der Schwarzbeinigkeit. Schweiz. Landw. Monatshefte. 11 : 285-291. 1933. Abst. Rev. App. Mycol. 13 : 223. 1934.

5. Laar, J. H. J. van de. Onderzeokingen over *Ophiobolus graminis* Sacc. en *Ophiobolus herpotrichus* (Fr.) Sacc. en over de door deze fungi veroorzaakte ziekten van *Triticum vulgare* Vill. en andere Gramineae. H. Veenman en Zonan, Wageningen. 1931.

6. Moritz, O. Weitere Studien über die Ophiobolose des Weizens. Mitt. Biol. Reichsanst. für Land– und Forstwirtschaft 20 : 1 : 27-48, 1932. Abst. Rev. App. Mycol. 12 : 1 : 19. 1933.

7. Padwick, G. W. Biologic strains of *Ophiobolus graminis* Sacc. Ann. App. Biol. 23 : 1 : 45-56. 1936.

8. Russell, R. C. Studies of take-all and its causal organism, *Ophiobolus graminis* Sacc. Dom. of Canada Dept. Agric. Bul. No. 170, New Series. 1934.

# FALL SPRAY INJURY TO PEACH TREES[1]

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In spite of its numerous advantages, the practice of spraying peach trees in late autumn has been regarded with suspicion in the Niagara Peninsula, because cases of injury, mainly to blossom buds, following fall-spray with dormant strength lime-sulphur were reported at Vineland, Ontario (1), a few years ago. At the time it was considered that the spray, by breaking the rest period, had rendered the buds subject to low temperature injury. In order to have had this effect, it would have been necessary for the spray material to have penetrated into the tissues of the host. That this does not usually happen has been demonstrated in the laboratory orchard at St. Catharines where, during ten years of experimentation, no injury resulting from the practice of either fall or winter spraying has been observed.

In March, 1938, however, attention was called to a commercial orchard on the shore of Lake Ontario, about 5 miles from the laboratory, where injury had occurred on trees sprayed with 1 : 7 lime-sulphur on November 25, 1937. Upon investigation it was found that the injury was mainly confined to weak slender twigs, evidently those formed late in the growing season; the more robust twigs had apparently escaped serious damage. Many of the affected twigs had been killed entirely, either directly or indirectly, by the spray material, but in others the injury was restricted to small necrotic areas around leaf scars. Frequently one leaf scar would be found covered with spray residue while the next one on the other side of the twig would have none. Almost invariably injury was associated with the presence of spray residue on the surface of the scar.

Free-hand sections, both from injured and from uninjured leaf bases, were prepared for microscopic examination. As reported in a previous paper (2), the tissue below the point of abscission normally dies back for a distance of a millimetre or more (Plate I), to form what may be called a protective layer. Sooner or later a periderm is laid down delimiting dead from living tissue and the protective layer eventually sloughs off. However, in none of the sections examined in the present studies was there any evidence of periderm formation, even as late as March, 1938 (Plate I, E). Thus the sole barrier to penetration through the leaf scar during the fall and winter was the protective layer of dead tissue. In those leaf bases which showed definite injury there was evidence that the spray solution has penetrated and bleached this protective layer (Plate I, A, B) which is normally dark brown in colour. Furthermore, small deposits of minute rhombic crystals, both prismatic and pyramidal (Plate II, C), formed over the surface of the bleached areas, particularly towards their inner limits and sometimes even at the inner border of the protective layer (Plate I, A; Plate II, A). The form of these crystals would suggest that

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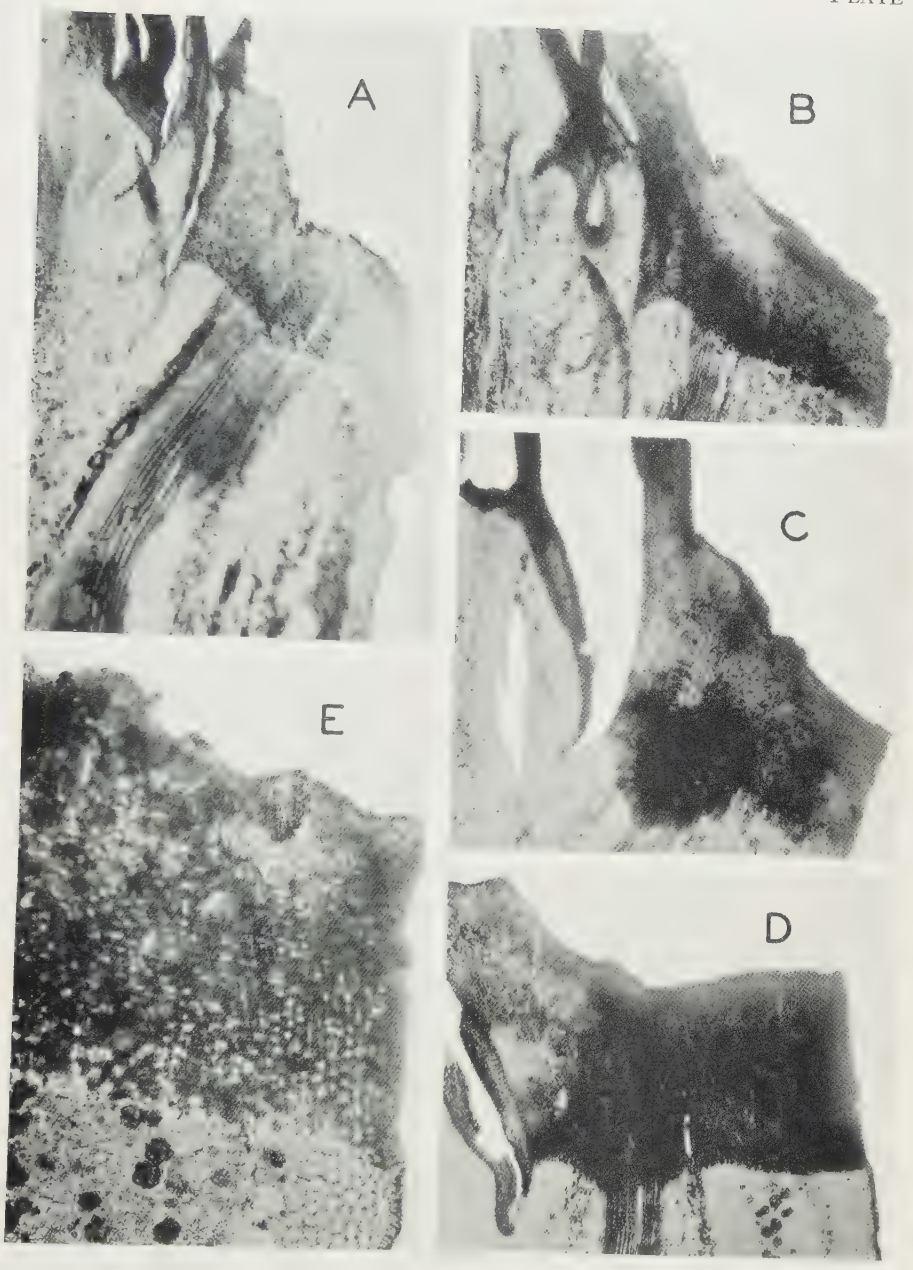


PLATE I. A–D: Leaf bases showing spray residue on upper surface and varying degrees of bleaching in the protective layer. Note also discoloured cortical cells at lower centre to right of A. A, B are from affected orchard; C, D from laboratory orchard. Crystalline deposits present in all but more readily discernible in A. (40×).

E: Uninjured leaf base, from affected orchard, showing absence of periderm. Note non-occurrence of bleaching. (125×).

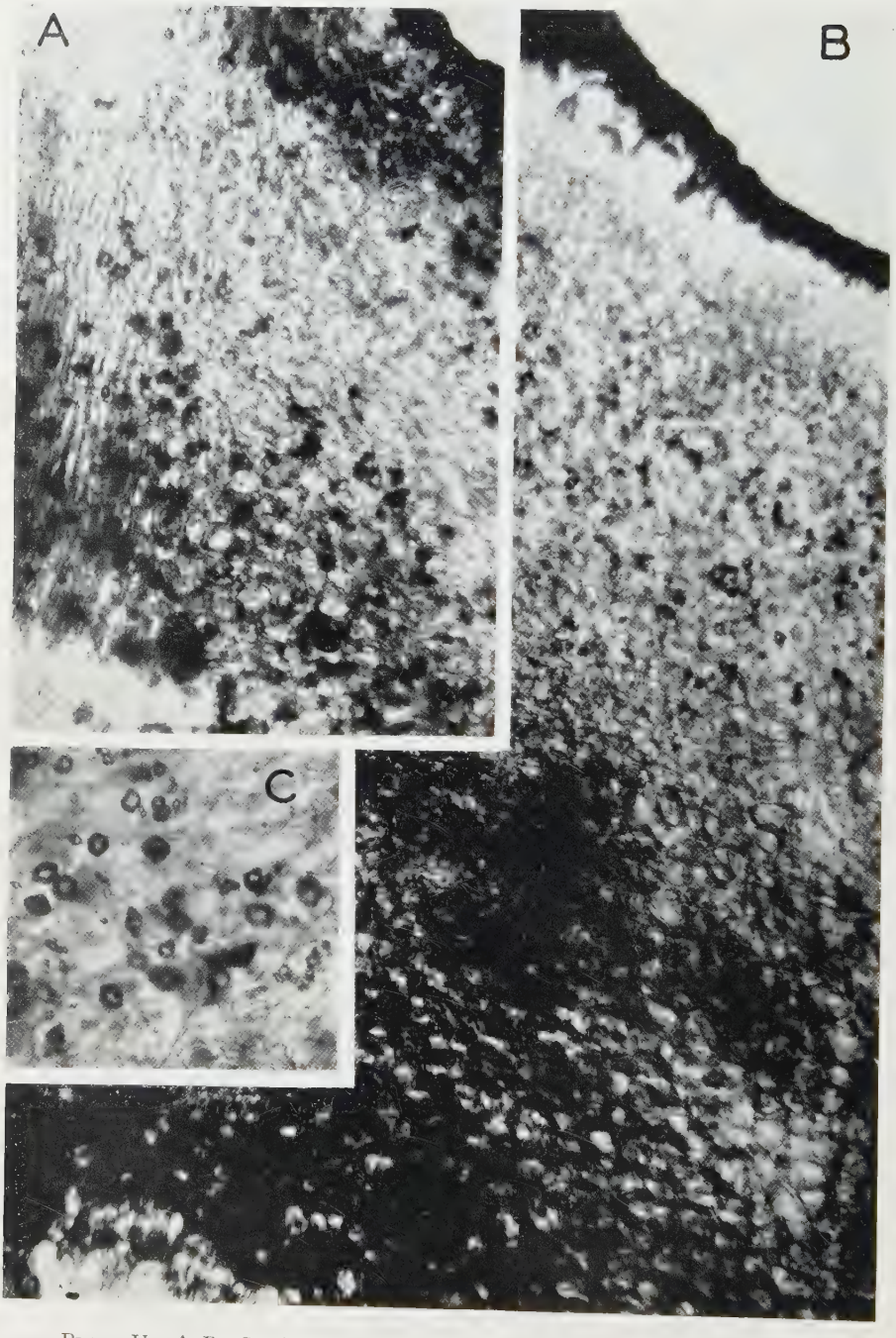


PLATE II. A–B: Sections of protective layer of leaf bases from affected orchard (A) and from laboratory orchard (B), showing spray residue, extreme upper right; bleached area with crystals, in B merging into darker non-bleached part of protective layer; and living cortical tissue at extreme lower left. Note penetration to approximately the same depth in both (250×). C: Crystals greatly enlarged (500×).

they were of elemental sulphur. If so, they were probably precipitated by the reaction of the mounting solution, in this case lacto-phenol, with the lime-sulphur either absorbed in the dead cells of the protective layer or combined with their decomposition products. Neither bleached zones nor crystalline deposits were present in the leaf bases from non-sprayed trees or in those not coated with spray residue (Plate I, E). It is probable that penetration in some cases also occurred directly by way of the leaf traces, particularly if the latter were not filled with wound-gum. Where injury was visible to the naked eye, the discoloration of cortical tissues and leaf traces immediately underlying the protective layer was apparent in the sections (Plate I, A).

Trees in the Laboratory orchard sprayed with lime-sulphur November 6, 1937, were also examined in March, 1938, for purposes of comparison. Careful search disclosed no injury from fall-spraying, even in the more slender twigs, although, as in those from the other orchard, no periderm was present in the leaf bases. However, beneath leaf scars covered with spray residue, bleaching, with the accompanying deposits of crystals, as in injured twigs, was observed in the outer part of the protective layer although in no case had penetration reached the living cells (Plate I, C, D; Plate II, B). The nearest approach to injury observed in leaf bases from the Laboratory orchard is shown in Plate I, C, where a portion of the leaf trace appears to have been affected. By comparing the illustrations of the material from the two orchards, it will be noticed that the protective layer was usually thicker in that from the Laboratory orchard (cf. A, B and C, D, Plate I). This is most strikingly evident in Plate II, which shows that while the depth of penetration into the protective layer, as indicated by the thickness of the bleached part of each, was actually about the same in both cases, the layer was thick enough to protect the living tissue in one instance but not in the other.

The evidence submitted here indicates that when injury from fall-spraying with lime-sulphur does take place, the leaf scar with its leaf traces is one of the main avenues of penetration. The fact that such injury is of infrequent occurrence may be taken as ample, even if indirect, proof not only that lime-sulphur cannot penetrate heavily cuticularised tissue, but also that the leaf scar is not usually vulnerable. The effectiveness of the leaf scar barrier is, of course, greatest when the periderm is produced in the fall. Otherwise it depends upon the thickness of the so-called protective layer and perhaps also upon the density or quantity of the decomposition product, in that region. Each of these factors again is affected by environmental conditions and cultural practices, both of which vary with locality and season. Thus, in some seasons fall spray injury would probably not occur in any locality, while in other seasons it could be expected to occur in certain orchards but not in others. However, though complete penetration of the protective layer may be comparatively rare, once it is effected injury results either directly from the toxic action of the lime-sulphur or indirectly from some other effect. On the other hand, it is possible that twigs subject to such damage may be constitution-

ally weak in other respects and that the spray injury, which otherwise would be localized, may initiate or stimulate processes of dissolution already inherent in such twigs.

## REFERENCES

1. Palmer, E. F. Fall spraying of peach trees. Ann. Report Ontario Fruit Growers' Association for year 1926 : 78-79. 1927.

2. Willison, R. S. Peach canker investigations. III. Further notes on incidence contributing factors and related phenomena. Can. J. Research. C, 15 : 324-339. 1937.

# MINERAL COMPOSITION OF SOILS AND FORAGE CROPS IN EASTERN CANADA

## I. Timothy Hay and Oat Straw

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Phosphorus deficiency in livestock has been reported to exist in Florida, Michigan, Montana, Minnesota, Texas, Wisconsin, Washington, Pennsylvania, and in many foreign countries. Cattle and sheep appear to be relatively immune to acalcicosis, though workers have reported a falling off in milk production and fragile bones due to low calcium rations. In many instances, the reported phosphorus deficiencies have been diagnosed by studying the response in growth and milk production to the feeding of mineral supplements but the actual composition of the forage and soil was not determined.

Daniel and Harper (2), working with mature prairie grass, showed that there was not a significant relationship between calcium and phosphorus of the forage and "base exchange calcium" and "easily soluble phosphorus" of the soil. Holtz (5), and Weathers (10) showed that soil type was an important factor in determining the composition of the plant. Austin (1) concluded that soil type was a greater factor than moderate applications of fertilizer. Ellis and Caldwell (3) reported that the mineral content of Manitoba hays was influenced by climatic and seasonal variations and, in some cases, by fertilizer treatment.

Holcomb (4), in an examination of Quebec timothy hay, showed that it was deficient in calcium as compared with values established by other investigators. Pugsley and McKibbin (8) found that the calcium content of Quebec timothy hay was low but that the calcium content of clover hay appeared normal. They further concluded that the calcium content of the two hays increased directly as the total calcium of the clay loam soils in which they were grown. A statistical examination of their data by the present authors did not substantiate this conclusion.

A study of the calcium and phosphorus contents of timothy hay and oat straw, as fed in Eastern Canada, was initiated by the Division of Chemistry, Ottawa, in 1936. The investigation was undertaken at the request of the Eastern Section of the Canadian Society of Animal Production following a discussion of the mineral content of home-grown livestock feeds with particular reference to deficiencies of these minerals reported in certain localities. Timothy hay and oat straw were chosen because they were the only widely grown crops of which it was possible to obtain pure samples. The result of the preliminary work was reported by Ripley and Hamilton (9) at the 1937 Annual Meeting of the Canadian Society of Animal Production. They concluded that "Due to so many variable factors, little or no correlation could be found between the mineral content

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of the forages and the observed deficiencies in the livestock, the type of soil and other points covered in the questionnaire. The low mineral content appeared to be equally as prevalent on heavy soils as on light soils and low mineral content as determined by chemical analysis was not always associated with observed mineral deficiencies in the animals."

This investigation was continued during 1937 and broadened to include samples of soil as well as of forage. The 1936 samples were collected from the mows of selected farms and there were no records of such factors as stage of maturity, weathering, and contamination from other plants. In an endeavour to eliminate such variables, the 1937 samples were collected in the field and all foreign plant materials removed so as to provide pure timothy hay or oat straw. At the same time samples of the surface soil were taken from the immediate area. All samples were air-dried and shipped to the Division of Chemistry.

The Division of Illustration Stations was responsible for the collection of samples from Illustration Stations, and the Division of Field Husbandry for samples from Branch Farms and Stations and for the threshing of the oat straw.

The Division of Chemistry made the chemical analyses. The timothy hay and oat straw samples were analysed for nitrogen, calcium and phosphorus. The soil samples were analysed for nitrogen, loss on ignition, total and exchangeable magnesium and calcium, total and soluble phosphorus, and pH. The exchangeable soil calcium and magnesium were those fractions of soil calcium and magnesium soluble in neutral, approximately normal ammonium acetate. The soluble phosphorus as determined by the Lohse and Ruhnke method (6) was the amount of phosphorus soluble in a dilute solution of acid potassium sulphate. In this paper the data for nitrogen, calcium, phosphorus, and pH value have been studied. These data have been grouped by districts and by soil types. Information with respect to mineral deficiency symptoms and fertilizer treatment, as supplied in a questionnaire accompanying each set of samples, has been studied. The classification according to districts was that supplied by the Division of Illustration Stations, *viz.*, Prince Edward Island, Nova Scotia, New Brunswick, Eastern Quebec, Central Quebec, Western Quebec and Eastern Ontario, and Northern Quebec and Northern Ontario (seven districts in all).

## TIMOTHY HAY AND SOILS BY DISTRICTS

The summary data for timothy hay and soil have been included in Table 1. The samples have been grouped by districts, and the standard error and coefficient of variation for each mean have been tabulated to indicate the variability in composition of forages or soils from any one district. There were no significant differences between phosphorus or nitrogen contents of timothy hays from the various districts. The calcium content of timothy hays from Nova Scotia was higher than those from Prince Edward Island, New Brunswick, Central Quebec, and Western Quebec and Eastern Ontario. In this connection, it might be pointed out that 36 of the 38 samples representing Nova Scotia were from experimental

TABLE 1.—AVERAGE CHEMICAL COMPOSITION OF TIMOTHY HAY AND SOIL BY DISTRICTS

(Dry matter basis)

| District | No. of paired samples | | Timothy hay | | | Soil | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Calcium | Phosphorus | Nitrogen | Calcium | | Phosphorus | | Nitrogen total | Loss on ignition | Magnesium | | pH |
| | | | | | | Total | Exchang. | Total | Soluble | | | Total | Exchang. | |
| | | | % | % | % | % | % | % | p.p.m. | % | % | % | % | |
| Prince Edward Island | 14 | Mean | 0.39 | 0.16 | 0.95 | 0.44 | 0.09 | 0.074 | 20 | 0.16 | 4.57 | 0.55 | 0.006 | 6.3 |
| | | C.V. | 27.4 | 13.7 | 17.5 | 31.4 | 47.6 | 32.7 | 40.2 | 27.3 | 25.7 | 66.4 | 72.8 | 8.8 |
| | | S.E. | ±0.029 | ±0.006 | ±0.044 | ±0.037 | ±0.011 | ±0.0065 | ±2.1 | ±0.012 | ±0.314 | ±0.097 | ±0.0001 | ±0.15 |
| Nova Scotia | 38 | Mean | 0.55 | 0.14 | 1.09 | 0.60 | 0.13 | 0.041 | 23 | 0.20 | 6.58 | 0.58 | 0.024 | 6.3 |
| | | C.V. | 35.4 | 25.5 | 16.7 | 34.1 | 46.9 | 51.1 | 69.5 | 30.9 | 24.9 | 46.5 | 100.7 | 5.5 |
| | | S.E. | ±0.032 | ±0.006 | ±0.030 | ±0.033 | ±0.010 | ±0.0034 | ±2.6 | ±0.010 | ±0.265 | ±0.044 | ±0.0040 | ±0.056 |
| New Brunswick | 27 | Mean | 0.43 | 0.14 | 0.95 | 0.63 | 0.14 | 0.088 | 21 | 0.27 | 7.63 | 0.66 | 0.012 | 5.8 |
| | | C.V. | 25.1 | 26.0 | 12.9 | 38.0 | 59.1 | 37.5 | 56.1 | 52.6 | 45.8 | 40.7 | 92.4 | 7.9 |
| | | S.E. | ±0.021 | ±0.007 | ±0.024 | ±0.046 | ±0.016 | ±0.0063 | ±2.2 | ±0.027 | ±0.672 | ±0.051 | ±0.0022 | ±0.088 |
| Eastern Quebec | 13 | Mean | 0.44 | 0.18 | 1.11 | 0.80 | 0.22 | 0.103 | 35 | 0.35 | 10.65 | 0.96 | 0.022 | 5.8 |
| | | C.V. | 33.1 | 38.5 | 18.9 | 37.2 | 64.6 | 45.3 | 129.6 | 50.1 | 66.8 | 38.3 | 78.3 | 7.6 |
| | | S.E. | ±0.040 | ±0.020 | ±0.058 | ±0.082 | ±0.040 | ±0.0129 | ±12.6 | ±0.049 | ±1.974 | ±0.102 | ±0.0047 | ±0.12 |
| Central Quebec | 18 | Mean | 0.42 | 0.15 | 1.13 | 1.31 | 0.14 | 0.101 | 37 | 0.28 | 7.41 | 0.62 | 0.012 | 6.1 |
| | | C.V. | 24.9 | 19.6 | 13.4 | 62.7 | 50.3 | 27.0 | 79.8 | 23.8 | 28.0 | 33.5 | 69.6 | 9.0 |
| | | S.E. | ±0.024 | ±0.007 | ±0.036 | ±0.193 | ±0.017 | ±0.0064 | ±7.0 | ±0.016 | ±0.489 | ±0.049 | ±0.0020 | ±0.13 |
| Western Quebec and Eastern Ontario | 22 | Mean | 0.34 | 0.16 | 1.00 | 2.09 | 0.23 | 0.133 | 74 | 0.25 | 7.85 | 1.02 | 0.035 | 6.3 |
| | | C.V. | 28.9 | 18.6 | 13.7 | 23.3 | 79.7 | 98.8 | 81.2 | 39.7 | 34.5 | 44.7 | 93.4 | 7.8 |
| | | S.E. | ±0.021 | ±0.006 | ±0.029 | ±0.104 | ±0.039 | ±0.0279 | ±12.8 | ±0.021 | ±0.578 | ±0.097 | ±0.0070 | ±0.11 |
| Northern Quebec and Northern Ontario | 18 | Mean | 0.45 | 0.15 | 1.14 | 1.68 | 0.30 | 0.088 | 70 | 0.29 | 10.20 | 1.21 | 0.047 | 5.8 |
| | | C.V. | 61.6 | 13.9 | 19.5 | 23.1 | 55.1 | 28.7 | 48.7 | 53.4 | 46.2 | 43.6 | 45.1 | 9.5 |
| | | S.E. | ±0.065 | ±0.005 | ±0.052 | ±0.092 | ±0.039 | ±0.006 | ±8.0 | ±0.037 | ±1.111 | ±0.124 | ±0.0050 | ±0.13 |

TABLE 2.—SOIL AND TIMOTHY HAY—SUMMARY OF CORRELATION COEFFICIENTS

| District | No. of paired samples | Exchangeable calcium in soil with calcium in hay | Soluble phosphorus in soil with phosphorus in hay | Nitrogen in soil with nitrogen in hay | Exchangeable calcium in soil with pH of soil | Soluble phosphorus in soil with pH of soil | Coefficient necessary for 5% level of significance |
|---|---|---|---|---|---|---|---|
| Prince Edward Island | 14 | +0.56 | +0.32 | +0.10 | +0.13 | −0.48 | 0.53 |
| Nova Scotia | 38 | +0.24 | +0.41 | +0.21 | +0.62 | −0.24 | 0.32 |
| New Brunswick | 27 | +0.35 | +0.54 | +0.55 | +0.25 | +0.20 | 0.38 |
| Eastern Quebec | 13 | +0.28 | −0.06 | −0.31 | +0.57 | +0.34 | 0.55 |
| Central Quebec | 18 | +0.52 | −0.03 | +0.28 | +0.67 | +0.15 | 0.47 |
| Western Quebec and Eastern Ontario | 22 | +0.14 | +0.23 | −0.05 | +0.46 | +0.36 | 0.42 |
| Northern Quebec and Northern Ontario | 18 | +0.25 | +0.17 | +0.40 | +0.61 | +0.50 | 0.47 |
| All districts | 150 | +0.05 | +0.13 | +0.24 | +0.26 | +0.16 | 0.19 |

TABLE 3.—AVERAGE CHEMICAL COMPOSITION OF OAT STRAW AND SOIL BY DISTRICTS

(Dry matter basis)

| District | No. of paired samples | | Oat straw | | | Soil | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Calcium | | Phosphorus | | Nitrogen total | Loss on ignition | Magnesium | | pH |
| | | | Calcium | Phosphorus | Nitrogen | Total | Exchang. | Total | Soluble | | | Total | Exchang. | |
| | | | % | % | % | % | % | % | p.p.m. | % | % | % | % | |
| Prince Edward Island | 11 | Mean | 0.37 | 0.12 | 0.70 | 0.38 | 0.09 | 0.075 | 16 | 0.15 | 4.52 | 0.37 | 0.006 | 6.2 |
| | | C.V. | 25.5 | 47.4 | 37.4 | 33.0 | 59.6 | 46.5 | 33.2 | 27.5 | 20.9 | 33.9 | 77.3 | 6.3 |
| | | S.E. | ±0.028 | ±0.017 | ±0.079 | ±0.037 | ±0.017 | ±0.0105 | ±1.6 | ±0.012 | ±0.285 | ±0.038 | ±0.0015 | ±0.12 |
| Nova Scotia | 11 | Mean | 0.39 | 0.08 | 0.58 | 0.69 | 0.16 | 0.066 | 30 | 0.18 | 6.52 | 0.64 | 0.020 | 6.0 |
| | | C.V. | 31.4 | 46.5 | 33.3 | 35.3 | 40.8 | 30.2 | 89.2 | 29.1 | 15.3 | 15.9 | 108.3 | 9.9 |
| | | S.E. | ±0.037 | ±0.012 | ±0.058 | ±0.074 | ±0.020 | ±0.0061 | ±8.1 | ±0.015 | ±0.300 | ±0.031 | ±0.0066 | ±0.18 |
| New Brunswick | 21 | Mean | 0.41 | 0.13 | 0.70 | 0.60 | 0.12 | 0.090 | 20 | 0.24 | 7.16 | 0.67 | 0.012 | 5.8 |
| | | C.V. | 29.8 | 43.6 | 33.5 | 29.2 | 78.2 | 24.6 | 45.8 | 24.2 | 29.4 | 53.4 | 167.8 | 12.0 |
| | | S.E. | ±0.026 | ±0.012 | ±0.051 | ±0.038 | ±0.020 | ±0.0048 | ±2.0 | ±0.013 | ±0.459 | ±0.078 | ±0.0044 | ±0.15 |
| Eastern Quebec | 18 | Mean | 0.32 | 0.09 | 0.52 | 1.13 | 0.20 | 0.112 | 41 | 0.30 | 8.67 | 0.93 | 0.034 | 5.9 |
| | | C.V. | 29.2 | 46.1 | 29.5 | 48.1 | 40.4 | 26.0 | 156.8 | 35.2 | 53.0 | 27.8 | 106.5 | 7.1 |
| | | S.E. | ±0.022 | ±0.010 | ±0.036 | ±0.128 | ±0.019 | ±0.0068 | ±15.1 | ±0.025 | ±1.083 | ±0.061 | ±0.0085 | ±0.10 |
| Central Quebec | 18 | Mean | 0.38 | 0.12 | 0.74 | 1.44 | 0.15 | 0.107 | 72 | 0.25 | 7.43 | 0.70 | 0.021 | 6.1 |
| | | C.V. | 32.0 | 30.9 | 27.6 | 57.8 | 53.9 | 30.6 | 95.9 | 26.5 | 27.2 | 37.5 | 89.3 | 8.1 |
| | | S.E. | ±0.028 | ±0.008 | ±0.048 | ±0.196 | ±0.019 | ±0.0077 | ±16.2 | ±0.016 | ±0.476 | ±0.062 | ±0.0043 | ±0.12 |
| Western Quebec and Eastern Ontario | 15 | Mean | 0.36 | 0.14 | 0.82 | 1.65 | 0.18 | 0.120 | 61 | 0.26 | 7.78 | 0.95 | 0.050 | 6.1 |
| | | C.V. | 25.1 | 41.0 | 35.6 | 32.9 | 57.5 | 65.4 | 81.1 | 45.5 | 40.2 | 40.3 | 68.3 | 5.2 |
| | | S.E. | ±0.023 | ±0.015 | ±0.075 | ±0.141 | ±0.026 | ±0.0202 | ±12.8 | ±0.031 | ±0.808 | ±0.099 | ±0.0088 | ±0.08 |
| Northern Quebec and Northern Ontario | 19 | Mean | 0.30 | 0.11 | 0.76 | 1.83 | 0.26 | 0.109 | 82 | 0.27 | 8.56 | 1.18 | 0.043 | 6.1 |
| | | C.V. | 22.7 | 48.8 | 50.1 | 31.1 | 51.4 | 43.3 | 64.0 | 42.4 | 46.9 | 34.9 | 41.9 | 9.6 |
| | | S.E. | ±0.015 | ±0.012 | ±0.088 | ±0.131 | ±0.031 | ±0.0108 | ±12.1 | ±0.027 | ±0.920 | ±0.094 | ±0.0041 | ±0.13 |

plots at Nappan Experimental Farm. Prince Edward Island soils were lowest in both total and exchangeable calcium. The Maritime soils, as a whole, tended to be lower in calcium than Quebec or Ontario soils. Nova Scotia soils were lowest in total phosphorus and the Maritime soils were lower in soluble phosphorus than those from more westerly points. There were no great differences between districts in total magnesium but P.E.I. soils were lowest in exchangeable magnesium. Differences in pH were not highly significant.

The co-variations of certain soil constituents with timothy hay constituents have been measured by means of the correlation coefficient and the coefficients are given in Table 2. In general, the coefficients were positive but they were significant at the 5% level in only a few cases. There was no over-all relationship between exchangeable calcium in soil and calcium in plant, soluble phosphorus in soil and phosphorus in plant, or soluble phosphorus in soil and pH of soil. There was a significant correlation of nitrogen in soil with nitrogen in timothy and of exchangeable calcium in soil with pH of soil.

## OAT STRAW AND SOIL BY DISTRICTS

The samples of oat straw and soil have also been grouped by districts and summary data are given in Table 3. There were no significant differences between districts in the calcium or phosphorus content of oat straw. The same general conclusions were drawn from this group of soils as from the group examined with the timothy hay. That is, the P.E.I. soils were lowest in total and exchangeable calcium and the Maritime soils, as a group, were lower in calcium than Quebec and Ontario soils.

Table 4 includes the correlation coefficients of various oat straw constituents with soil constituents. There was no over-all relationship between exchangeable calcium in the soil and calcium in the straw, soluble phosphorus in the soil and phosphorus in the straw, or nitrogen in the soil and nitrogen in the straw. The exchangeable calcium and the soluble phosphorus in the soil were both significantly correlated with the pH of the soil. Taking the timothy and straw soils as one group (263 samples), the correlation coefficient of exchangeable calcium with pH was +0.36 and of soluble phosphorus with pH +0.24. These coefficients were significant at the 1% point.

The variability in both plant and soil composition within districts showed that such a grouping was of little value in establishing a relationship between composition of crops and soils. The correlation data confirmed the conclusion of Daniel and Harper (2) in that there was no relationship between the calcium and phosphorus of the crops and the exchangeable calcium and soluble phosphorus of the soils.

## PLANT AND SOIL COMPOSITION IN RELATION TO SOIL TYPE

In investigating the relationship of plant and soil composition to soil type, all soil samples were classified as either "clay loam" or "sandy loam". The mean calcium and phosphorus contents of forages and soils according

TABLE 4.—SOIL AND OAT STRAW—SUMMARY OF CORRELATION COEFFICIENTS

| District | No. of paired samples | Exchangeable calcium in soil with calcium in straw | Soluble phosphorus in soil with phosphorus in straw | Nitrogen in soil with nitrogen in straw | Exchangeable calcium in soil with pH of soil | Soluble phosphorus in soil with pH of soil | Coefficient necessary for 5% level of significance |
|---|---|---|---|---|---|---|---|
| Prince Edward Island | 11 | +0.59 | +0.39 | +0.15 | +0.84 | +0.54 | 0.60 |
| Nova Scotia | 11 | +0.31 | −0.09 | +0.24 | +0.51 | −0.27 | 0.60 |
| New Brunswick | 21 | +0.48 | +0.36 | −0.06 | +0.92 | +0.64 | 0.43 |
| Eastern Quebec | 18 | −0.11 | +0.06 | −0.25 | +0.59 | +0.52 | 0.47 |
| Central Quebec | 18 | +0.53 | −0.13 | +0.42 | +0.80 | +0.49 | 0.47 |
| Western Quebec and Eastern Ontario | 15 | +0.02 | +0.22 | +0.15 | −0.09 | +0.20 | 0.51 |
| Northern Quebec and Northern Ontario | 19 | +0.06 | +0.04 | +0.09 | +0.56 | +0.53 | 0.46 |
| All Districts | 113 | +0.04 | +0.04 | +0.06 | +0.51 | +0.35 | 0.19 |

to soil type are given in Table 5. The significance of the difference between means was tested, a 1% level of significance being considered significant. Both timothy hay and oat straw showed a significantly greater calcium content when grown on sandy loams than when grown on clay loams. The type of soil had no effect upon the phosphorus content of timothy. The phosphorus content of oat straw was slightly higher on the clay loams showing a significant difference at the 2% point. The total calcium, exchangeable calcium and soluble phosphorus contents of the soil were all significantly greater in clay loams than in sandy loams. The total phosphorus content of the two soil types were similar.

## THE EFFECT OF FERTILIZATION ON THE PHOSPHORUS CONTENT OF TIMOTHY HAY AND OAT STRAW

Ellis and Caldwell (3) have suggested that "The phosphate content of hay may be increased by the application of phosphatic fertilizers, if the phosphate in the soil is either low in quantity or not readily available; but, that the application of phosphate fertilizers to soil may not result in an increased phosphate content of the hay if normal crop yields are produced without fertilizer treatment."

In this present work, a number of samples of timothy hay and oat straw with the corresponding soils were collected from non-fertilized areas and from those which had received a phosphatic fertilizer in the form of commercial fertilizer or manure. It was thus possible to study, to a limited extent, the effect of fertilization on the composition of forages grown on the same soil types and under identical seasonal conditions.

Data for phosphorus content of timothy hay and soluble phosphorus of the soil from seven locations are given in Table 6. At Nappan, N.S., Penobsquis and Norton, N.B., where the soluble phosphorus contents of the untreated soils were respectively, 14, 8, and 9 p.p.m., the phosphorus contents of the forages were considerably below the average for the whole series; when phosphorus was applied to the soil there was an appreciable increase in the phosphorus content of the timothy hay. At Kentville, N.S. and Sussex, N.B. where the soluble phosphorus of the untreated soils was between 20 and 30 p.p.m. the phosphorus content of the timothy hays was above the average for the whole series and the application of phosphorus did not increase the phosphorus content of the forages. The supply of soluble phosphorus in the soil from Kapuskasing, Ont. was high and yet on both the treated and untreated soils the phosphorus in the hay was slightly below average. With an equally high content of soluble phosphorus in the soil at Ottawa, Ont., the phosphorus in the hays from both fertilized and unfertilized areas was above the average, and even with such a plentiful supply of soluble phosphorus in the soil the application of the fertilizer increased the phosphorus content of the forage. From such inconsistent data it was impossible to arrive at any definite conclusions in regard to the effect of phosphorus applied to the soil on the composition of the hay. However, when the soil was very low in soluble phosphorus as was the case of Nappan, N.S., and Penobsquis and Norton, N.B., there appeared to be some evidence that increasing the supply of soluble phosphorus in the soil increased the phosphorus content of the hay.

TABLE 5.—EFFECT OF SOIL TYPE UPON THE CHEMICAL COMPOSITION OF TIMOTHY HAY AND OAT STRAW

(Dry matter basis)

| Nature of crop | Nature of soil | Crop | | Soil | | | |
|---|---|---|---|---|---|---|---|
| | | | | Calcium | | Phosphorus | |
| | | Calcium % | Phosphorus % | Total % | Exchang. % | Total % | Soluble p.p.m. |
| Timothy hay | Clay loam | 0.39 ± 0.017 | 0.15 ± 0.011 | 1.33 ± 0.090 | 0.21 ± 0.017 | 0.087 ± 0.0057 | 57 ± 6.1 |
| Timothy hay | Sandy loam | 0.48 ± 0.017 | 0.15 ± 0.004 | 0.83 ± 0.071 | 0.14 ± 0.013 | 0.079 ± 0.0036 | 25 ± 2.4 |
| Oat straw | Clay loam | 0.34 ± 0.012 | 0.12 ± 0.007 | 1.42 ± 0.094 | 0.21 ± 0.014 | 0.102 ± 0.0063 | 65 ± 7.4 |
| Oat straw | Sandy loam | 0.39 ± 0.016 | 0.10 ± 0.007 | 0.85 ± 0.079 | 0.13 ± 0.012 | 0.097 ± 0.0165 | 30 ± 5.6 |

TABLE 6.—EFFECT OF FERTILIZATION UPON THE PHOSPHORUS CONTENT OF TIMOTHY HAY

| Location | Treatment | Soluble phosphorus in soil | Phosphorus in hay |
|---|---|---|---|
| | | p.p.m. | % |
| Nappan, N.S. | Fertilized (Av. of 6 plots) | 16 | 0.15 |
| | Non-fertilized (Av. of 9 plots) | 14 | 0.11 |
| Kentville, N.S. | Fertilized (Av. of 2 plots) | 26 | 0.18 |
| | Non-fertilized (Av. of 2 plots) | 27 | 0.18 |
| Sussex, N.B. | Fertilized | 20 | 0.18 |
| | Non-fertilized | 22 | 0.17 |
| Penobsquis, N.B. | Fertilized | 22 | 0.13 |
| | Non-fertilized | 8 | 0.09 |
| Norton, N.B. | Fertilized | 14 | 0.13 |
| | Non-fertilized | 9 | 0.10 |
| Kapuskasing, Ontario | Fertilized | 118 | 0.13 |
| | Non-fertilized | 111 | 0.13 |
| Ottawa, Ontario | Fertilized | 127 | 0.21 |
| | Non-fertilized | 98 | 0.18 |

Samples of oat straw were obtained from unfertilized and fertilized areas at seven locations and the phosphorus contents have been tabulated in Table 7. At Nappan, Kentville, N.S., and Currieburg, N.B., the soluble phosphorus of the untreated soils was low (6, 11, and 8 p.p.m., respectively) and this soil condition was reflected in the relatively low phosphorus content of the oat straws. The application of fertilizers containing phosphorus materially increased the percentage of this element in the straws. The soluble soil phosphorus at Harrow, Ont. was comparatively low while the phosphorus content of the straw was about the same as the average for the whole series. Nevertheless it was increased by phosphatic fertilization. At the other three locations where the soluble phosphorus content of the soils was relatively high, fertilization had no effect on the phosphorus content of the straws. The results for l'Assomption and Kapuskasing showed that even with a high soluble soil phosphorus the phosphorus content of the straw might be low. Again, there appeared to be some evidence that the application of soluble phosphates to soils which were relatively low in this constituent tended to increase the phosphorus content of the crop.

TABLE 7.—EFFECT OF FERTILIZATION UPON THE PHOSPHORUS CONTENT OF OAT STRAW

| Location | Treatment | Soluble phosphorus in soil | Phosphorus in oat straw |
|---|---|---|---|
| | | p.p.m. | % |
| Nappan, N.S. | Fertilized | 21 | 0.12 |
| | Fertilized | 17 | 0.13 |
| | Fertilized | 14 | 0.12 |
| | Non-fertilized | 5 | 0.04 |
| | Non-fertilized | 6 | 0.04 |
| | Non-fertilized | 8 | 0.03 |
| Kentville, N.S. | Fertilized | 17 | 0.13 |
| | Non-fertilized | 11 | 0.09 |
| Currieburg, N.B. | Fertilized | 11 | 0.14 |
| | Non-fertilized | 8 | 0.07 |
| Ste. Anne de la Pocatiere, Quebec | Fertilized | 30 | 0.12 |
| | Fertilized | 105 | 0.22 |
| | Non-fertilized | 34 | 0.15 |
| L'Assomption, Quebec | Fertilized | 109 | 0.14 |
| | Fertilized | 208 | 0.05 |
| | Fertilized | 167 | 0.06 |
| | Fertilized | 193 | 0.16 |
| Kapuskasing, Ontario | Fertilized | 117 | 0.04 |
| | Non-fertilized | 132 | 0.04 |
| Harrow, Ontario | Fertilized | 42 | 0.17 |
| | Non-fertilized | 14 | 0.12 |

## THE RELATION OF MINERAL CONTENT OF FORAGES TO REPORTED MINERAL DEFICIENCY SYMPTOMS IN LIVESTOCK

The following question was asked in the questionnaire sent out in connection with the collection of the samples:

> "Are there any evidences of mineral deficiencies in the forage crops fed to the cattle on farm from which the samples were procured as indicated by their chewing bones, wood, leather, iron or earth, particularly in the spring months?"

The answers to this enquiry were not entirely satisfactory. In some cases the question was ignored but in the majority of instances the reply was "yes", "no", or "slight". It was doubtful if this information was reliable. Certain of the samples of forages, however, were classified according to the "yes" and "no" replies to the above question and the calcium and phosphorus contents of each group were compared. The summary of these data is given in Table 8.

TABLE 8.—MEAN COMPOSITION OF FORAGES AS RELATED TO REPORTED MINERAL DEFICIENCIES

(Dry matter basis)

| Symptoms of mineral deficiency in livestock (questionnaire) | Timothy | | | Oat straw | | |
|---|---|---|---|---|---|---|
| | No. of samples | Calcium | Phosphorus | No. of samples | Calcium | Phosphorus |
| | | p.c. | p.c. | | p.c. | p.c. |
| "Yes" | 28 | 0.43 | 0.15 | 22 | 0.36 | 0.11 |
| "No." | 48 | 0.39 | 0.15 | 47 | 0.36 | 0.12 |

There was no relationship between calcium and phosphorus content of the forages and the symptoms of mineral deficiencies reported. These results indicated that either mineral deficiencies of livestock were not related to any one or two home grown crops or that the above symptoms were not accurate criteria of mineral deficiencies.

## AVERAGE COMPOSITION OF TIMOTHY HAY AND OAT STRAW FOR EASTERN CANADA

Since considerable data were available from this work it was considered advisable to tabulate average figures in conjunction with those of other workers Such summary tables would be of value not only in establishing average crop composition in Eastern Canada but in bringing to light any discrepancies resulting from the use of various analytical procedures.

TABLE 9.—COMPOSITION OF TIMOTHY HAY

(Dry matter basis)

| Authority | Locality | No. of samples | Calcium | Phosphorus | Nitrogen | Stage of maturity |
|---|---|---|---|---|---|---|
| | | | p.c. | p.c. | p.c. | |
| Morrison (7) | U.S.A. | 25 | 0.46 | 0.24 | 1.38 | Early bloom. |
| Morrison (7) | U.S.A. | 47 | 0.30 | 0.18 | 1.12 | Full bloom. |
| Holcomb (4) | Quebec | 9 | 0.07 | 0.12 | — | — |
| Pugsley & McKibbin (8) | Quebec | 14 | 0.04 | 0.17 | 1.10 | — |
| Ellis & Caldwell (3) | Manitoba | — | 0.16* | 0.14* | — | — |
| Thomas (unpublished) | Ontario | 267 | 0.31 | 0.16 | 1.19 | — |
| Ripley & Hamilton (9) | Eastern Canada | 85 | 0.40 | 0.12 | — | — |
| Wright & Woodward | Eastern Canada | 150 | 0.44 | 0.15 | 1.05 | ** |

* Air dry basis.

** That at which timothy normally harvested in the various districts. In most cases after full bloom.

TABLE 10.—COMPOSITION OF OAT STRAW

(Dry matter basis)

| Authority | Locality | No. of samples | Calcium | Phosphorus | Nitrogen |
|---|---|---|---|---|---|
| | | | p.c. | p.c. | p.c. |
| Morrison (7) | U.S.A. | 67 | 0.40 | 0.14 | 0.71 |
| Division of Chemistry, Ottawa (unpublished) | Manitoba | 15 | 0.43 | 0.08 | — |
| Ripley & Hamilton (9) | Eastern Canada | 110 | 0.32 | 0.08 | — |
| Wright & Woodward | Eastern Canada | 113 | 0.36 | 0.11 | 0.69 |

The data presented in Table 9 give the average composition of timothy hay and those in Table 10 the average composition of oat straw. The calcium values for timothy hay reported by Holcomb (4) and by Pugsley and McKibbin (8) were extremely low compared with those of other investigators, and did not appear representative of Quebec hays. The values for phosphorus content of Canadian timothy tended to be lower than those reported by Morrison (7). The data for oat straw showed that its calcium content was practically equal to that of timothy hay but that it was not as rich in phosphorus or nitrogen.

## SUMMARY AND CONCLUSIONS

Paired samples of timothy hay, oat straw and soil were collected from representative farms in Prince Edward Island, Nova Scotia, New Brunswick, Quebec, and Eastern Ontario and analyzed for nitrogen and various mineral constituents.

There was no relationship between calcium and phosphorus content of timothy hay or oat straw and the exchangeable calcium and soluble phosphorus of the soil. There was a significant positive correlation of the nitrogen of timothy hay with the nitrogen in the soil. The relationships between exchangeable calcium and pH of soil and between soluble phosphorus and pH of soil were positive and were significant at the 1% point.

The calcium content of both hay and straw was significantly greater when the crops were grown on sandy loams than when grown on clay loams. The clay loam soils were higher in total calcium, exchangeable calcium, and soluble phosphorus than the sandy loams.

There was some evidence that phosphatic fertilizers tended to increase the phosphorus content of hay or straw in certain instances where the soluble soil phosphorus was particularly low.

Reported instances of mineral deficiencies in livestock were not related to calcium or phosphorus content of hay or straw.

## ACKNOWLEDGMENT

The authors wish to acknowledge the assistance of Messrs. H. S. Hammond, H. H. Selwyn and the various assistants of the Soils and Plant Chemistry staffs who performed the analyses reported in this paper.

## LITERATURE CITED

1. Austin, R. H. Effect of soil type and fertilizer treatment on the composition of the soybean plant. Journ. Amer. Soc. Agron. 22 : 135-156. 1930.

2. Daniel, H. A., and Harper, H. J. The relation between total calcium and phosphorus in mature prairie grass and available plant food in soil. Jour. Amer. Soc. Agron. 26 ; 986-992. 1934.

3. Ellis, J. H. and Caldwell, O. G. Mineral content of Manitoba hays. Sci. Agr. 16 : 521-537. 1936.

4. Holcomb, R. The calcium and phosphorus content of some Quebec hays. Sci. Agr. 10 : 28-34. 1929.

5. Holtz, H. F. Effect of calcium and phosphorus content of various soil series in western Washington upon the calcium and phosphorus composition of oats, red clover and white clover. Wash. Agr. Exp. Sta. Bull. 243. 1930.

6. Lohse, H. W. and Ruhnke, G. N. Studies on readily soluble phosphate in soils. I. Extraction of readily soluble phosphate from soils by means of dilute acid potassium sulphate ($KHSO_4$). Soil Sci. 35 : 437-457. 1933.

7. Morrison, F. B. Feeds and Feeding. Table I. Appendix. The Morrison Publishing Company. 1936.

8. Pugsley, L. I. and McKibbin, R. R. Calcium relationships of forage crops. Canadian Journ. Res. 4 : 39-51. 1931.

9. Ripley, P. O. and Hamilton, S. N. The mineral content of timothy hay and oat straw as fed in Eastern Canada. Sci. Agr. 18 : 1-9. 1937.

10. Weathers, E. K. Mineral and nitrogen content of lespedezas and other hay crops in Tennessee. Tenn. Agr. Exp. Sta. Bul. 166. 1938.

## ERRATA

Volume XIX, No. 7. "Brown Rot of Peaches in Transit and Storage."

P. 469—line 7 : for "spot" read "rot."

P. 472—line 20: for "marked" read "marketed."

# THE THERMAL DEATH POINT OF CORN FROM LOW TEMPERATURES

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The question of how low a temperature husked corn on the cob will stand without serious damage to its germinating ability is one of perennial interest to Canadian corn growers. This being the case, the following investigations were undertaken with the hope of supplementing existing evidence.

Obviously a number of factors influence the damage which results from exposure to low temperatures. Two of the most potent of such factors are the moisture content of the corn at the time of exposure, and the severity of the cold to which it is subjected. Other factors which might influence the results secured are the duration of the treatment and the method of exposure.

## MATERIALS AND METHODS

A large number of ears of corn were available from a special co-operative test plot grown at the Experiment Station at Ridgetown, Ontario. This material included ears with a wide variation in moisture content, and provided an opportunity of securing sufficient material for the following four moisture groups:

*(a)* Low moisture content—below 15%.

*(b)* Medium moisture content—from 15 to 19.9%.

*(c)* Medium high moisture content—from 20 to 24.9%.

*(d)* High moisture content—25% and over.

The moisture content was determined by removing ten grams of kernels from each cop and extracting the moisture by a modified Brown-Duval method.

An excellent series of low temperature chambers in the Horticultural Building of the Ontario Agricultural College were made available for the investigation. The chambers in question permitted of the following temperature groups for the experiment:

1. Continuous temperature of −10° F.
2. Fluctuating temperature held alternately for 5-day periods at −10° F. and 0° F.
3. Continuous temperature of 0° F.
4. Fluctuating temperature held alternately for 5-day periods at 0° F. and 15° F.
5. Continuous temperature of 15° F.

[1] Professor of Field Husbandry.

6. Fluctuating temperature held alternately for 5-day periods at 15° F. and 32° F.
7. Continuous temperature of 32° F.
8. In addition to the foregoing, one lot of material was held at outside temperature.

The exact moisture content of each cob in the test was determined separately and recorded on a tag attached to the cob. The cobs were then sorted into their respective moisture groups and placed in a special moisture-proof container which held the moisture content approximately constant. A germination test was made of all corn at the beginning of the test, and any material in which the germination had been seriously impaired previous to the beginning of the test was discarded. A container of corn, representative of each of the 4 moisture groups was placed under each of the 8 temperature conditions. Samples of corn for germination purposes were removed at 5-day intervals, and the germination tests were made in pure quartz sand.

In some preliminary tests the wrapping of each cob in a medium weight cellophane was checked as a possible means of maintaining the moisture content. The results of this test indicated that under the conditions of the experiment the cellophane wrappings were not effective in preventing appreciable lowering of the moisture content in the high moisture series. The tin moisture-proof containers adopted had been tested quite thoroughly in refrigeration studies by the Horticultural Department of the Ontario Agricultural College and were found to be much more satisfactory in holding an approximately constant moisture content than was the cellophane wrapping when used in this connection.

An interesting observation was made during the course of the preliminary testing of the cobs of corn for moisture content. This was the fact that, particularly with cobs in which the moisture content was high, a very appreciable variation was obtained when sampling different sections of the cob. The extent and significance of this variation is being studied further in connection with a parallel series of investigations now in progress on the effect of high temperatures on the thermal death point of corn.

## EXPERIMENTAL RESULTS

The data secured are presented largely in the form of graphs. A few tables are also included in which the results of the germination tests of a number of cobs of a common moisture group are recorded for the various temperatures at which the tests were conducted.

The graphs in all cases represent the averages of all cobs held under similar conditions of temperature, and belonging to a common moisture group.

The numbers of cobs used for the various determinations were of necessity rather limited. As a consequence, the results secured must be considered as representing trends rather than final evidence of the effect of the varying conditions encountered in the experiment.

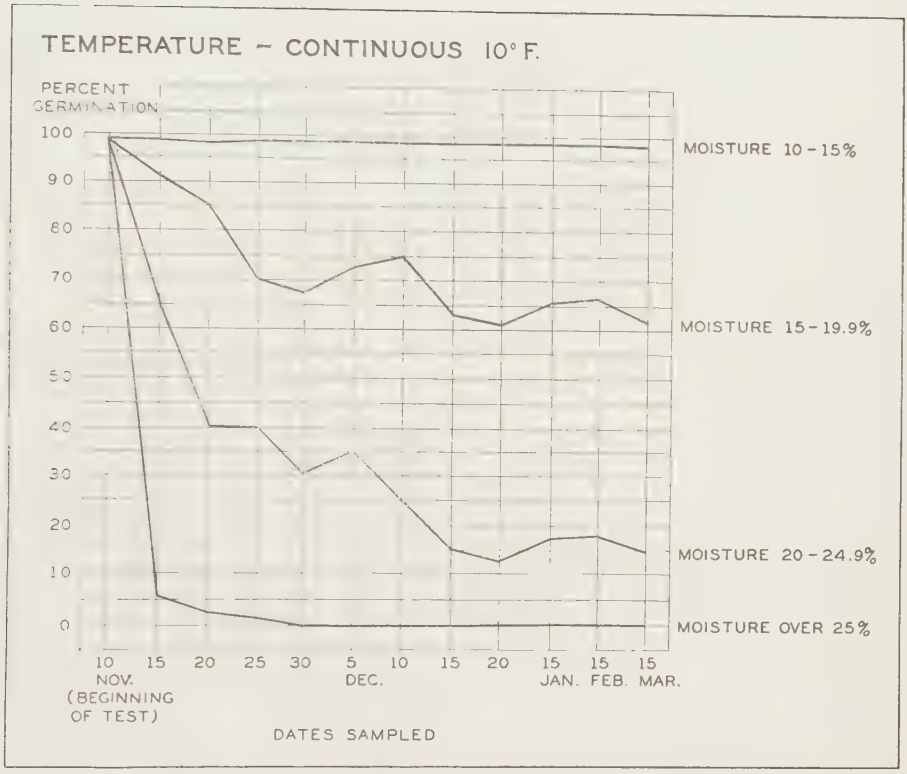


FIGURE 1

The data presented in Figure 1 indicate that at a temperature of −10° F., only corn which had below 15% moisture, was safe for storage. As the moisture content of each group increased, the degree of damage to germination was more pronounced. With the higher moisture content, the destruction of germination was very rapid, while in the case of the two mid-moisture groups, the lowering of germination was more gradual but progressive in its general trend.

The same general trend is evident in Figure 2 as was indicated by the data presented in Figure 1. However, the fluctuating temperature appeared to be a more effective damaging agent than the continuous temperature. This was particularly evident in the lower moisture groups where, for the only instance in the experiment, the moisture group between 12 and 14.9% showed definite damage after several weeks' exposure.

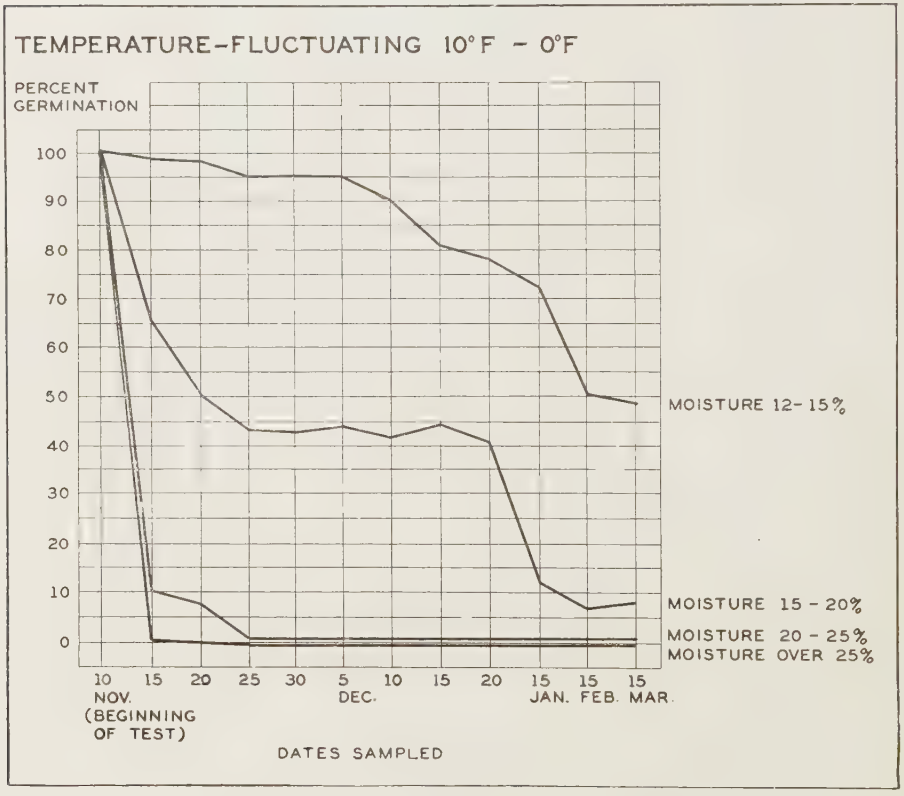


FIGURE 2

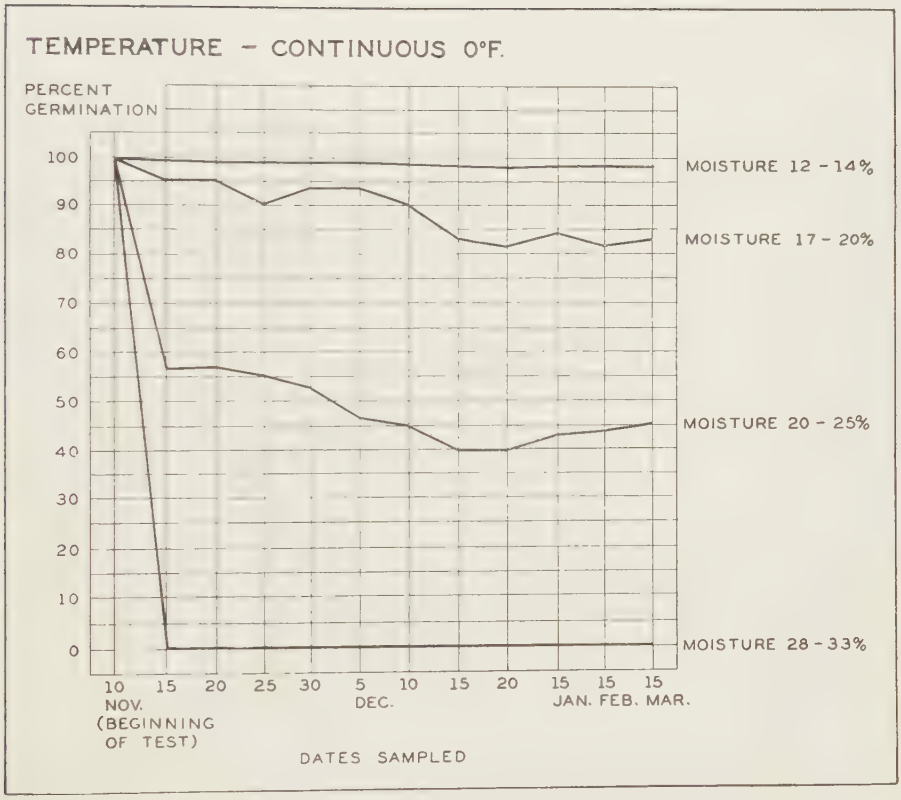
TEMPERATURE – CONTINUOUS 0°F.
PERCENT GERMINATION
100
90
80
70
60
50
40
30
20
10
0
MOISTURE 12 – 14%
MOISTURE 17 – 20%
MOISTURE 20 – 25%
MOISTURE 28 – 33%
10 15 20 25 30 5 10 15 20 15 15 15
NOV. (BEGINNING OF TEST)
DEC.
JAN. FEB. MAR.
DATES SAMPLED

FIGURE 3

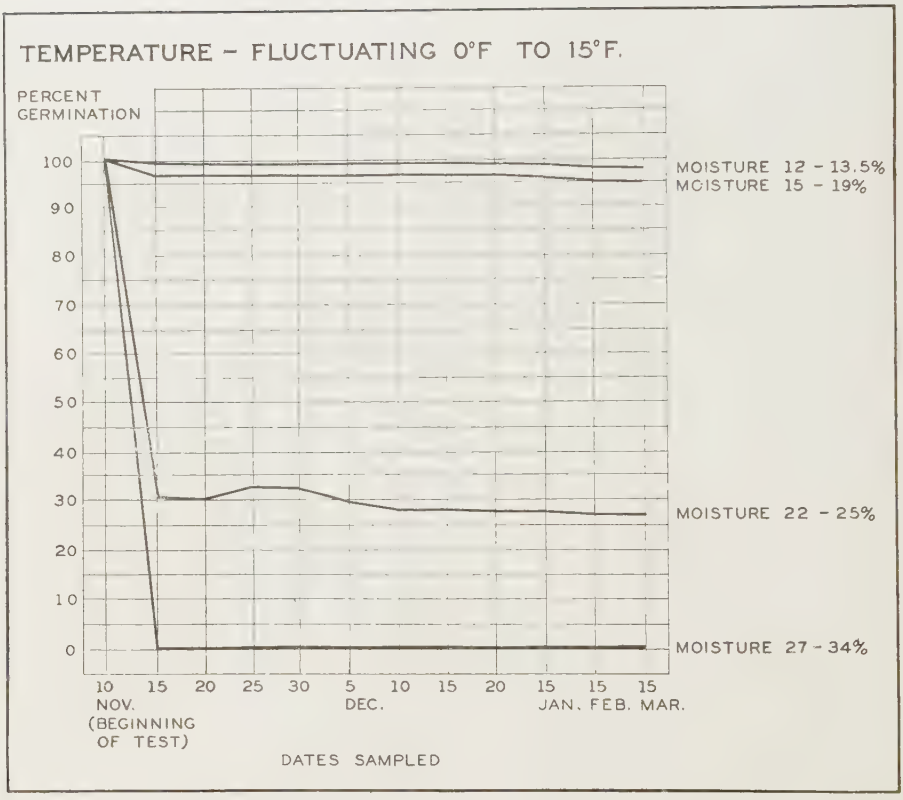
TEMPERATURE – FLUCTUATING 0°F TO 15°F.
PERCENT GERMINATION
100
90
80
70
60
50
40
30
20
10
0
MOISTURE 12 - 13.5%
MOISTURE 15 - 19%
MOISTURE 22 - 25%
MOISTURE 27 - 34%
10 15 20 25 30 5 10 15 20 15 15 15
NOV. (BEGINNING OF TEST)
DEC.
JAN. FEB. MAR.
DATES SAMPLED

FIGURE 4

The higher moisture groups again showed severe damage at the continuous temperature of 0° F. When the temperature was fluctuated from 0° F. to 15° F., the proportionate damage was materially increased in the two middle moisture groups.

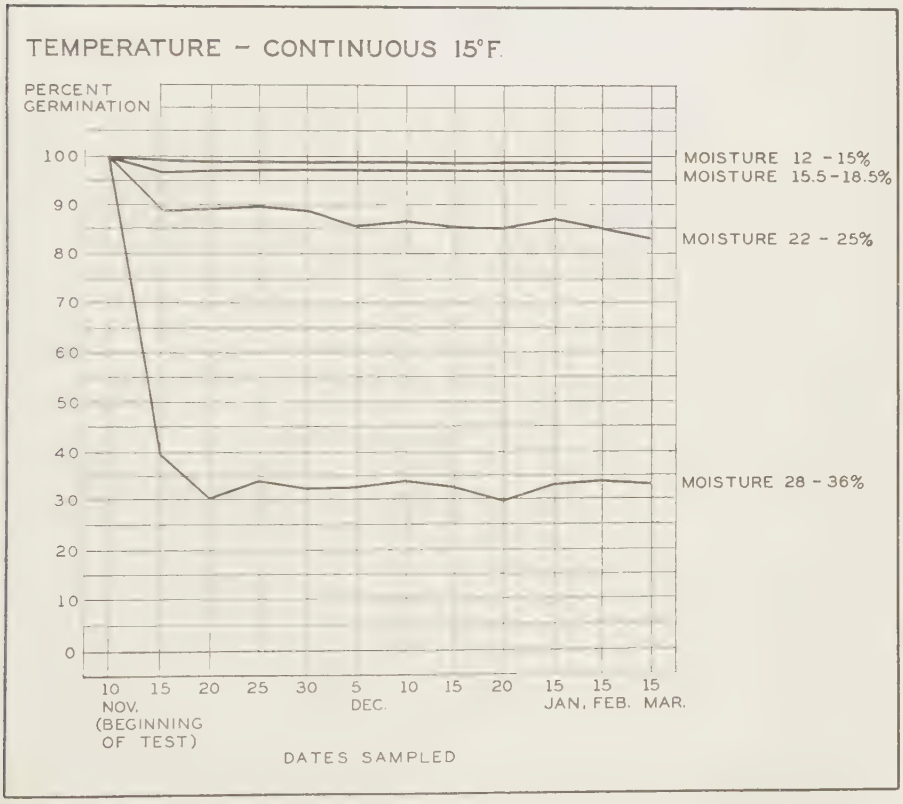


FIGURE 5

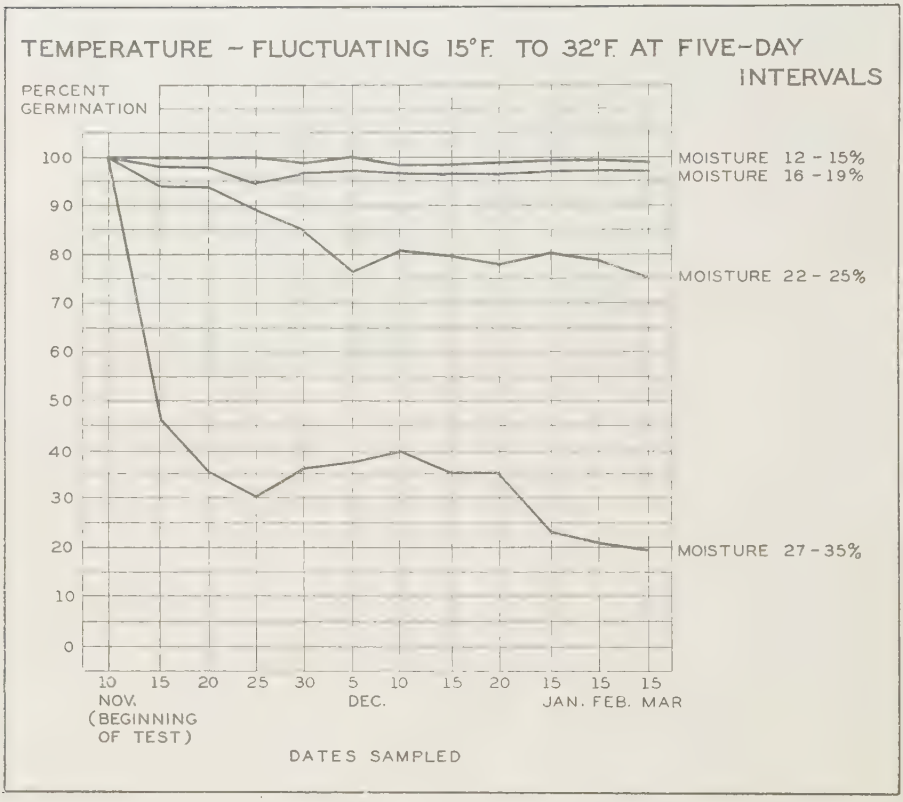
TEMPERATURE ~ FLUCTUATING 15°F. TO 32°F. AT FIVE-DAY INTERVALS
PERCENT GERMINATION
100
90
80
70
60
50
40
30
20
10
0
MOISTURE 12 - 15%
MOISTURE 16 - 19%
MOISTURE 22 - 25%
MOISTURE 27 - 35%
10 15 20 25 30 5 10 15 20 15 15 15
NOV. (BEGINNING OF TEST)
DEC.
JAN. FEB. MAR
DATES SAMPLED

FIGURE 6

Even at temperatures of 15° F. held continuously, or fluctuated between that temperature and 32° F., there was very serious loss in germination in the two higher moisture groups. The highest moisture group still showed sufficient damage to render it unfit for seed purposes.

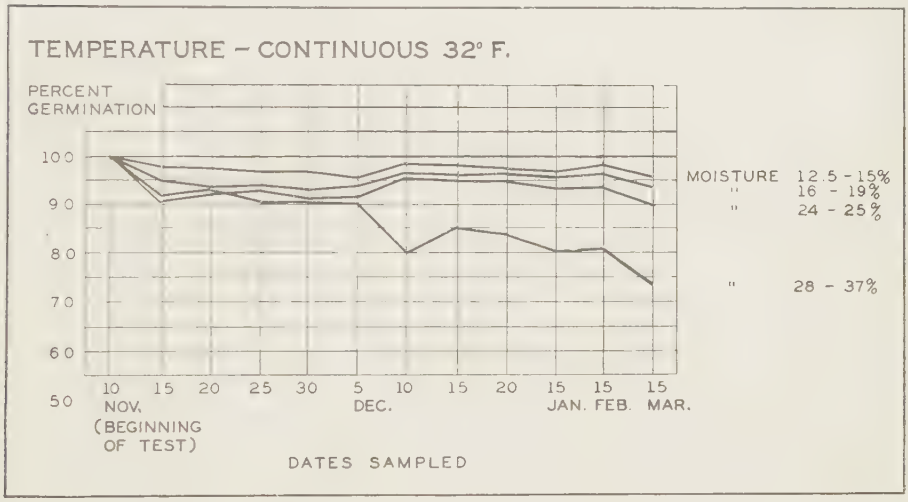


FIGURE 7

Figure 7 would indicate that even if the temperature did not fall below the freezing point, corn, with a high moisture content, might be expected to be appreciably reduced in germination during the storage season.

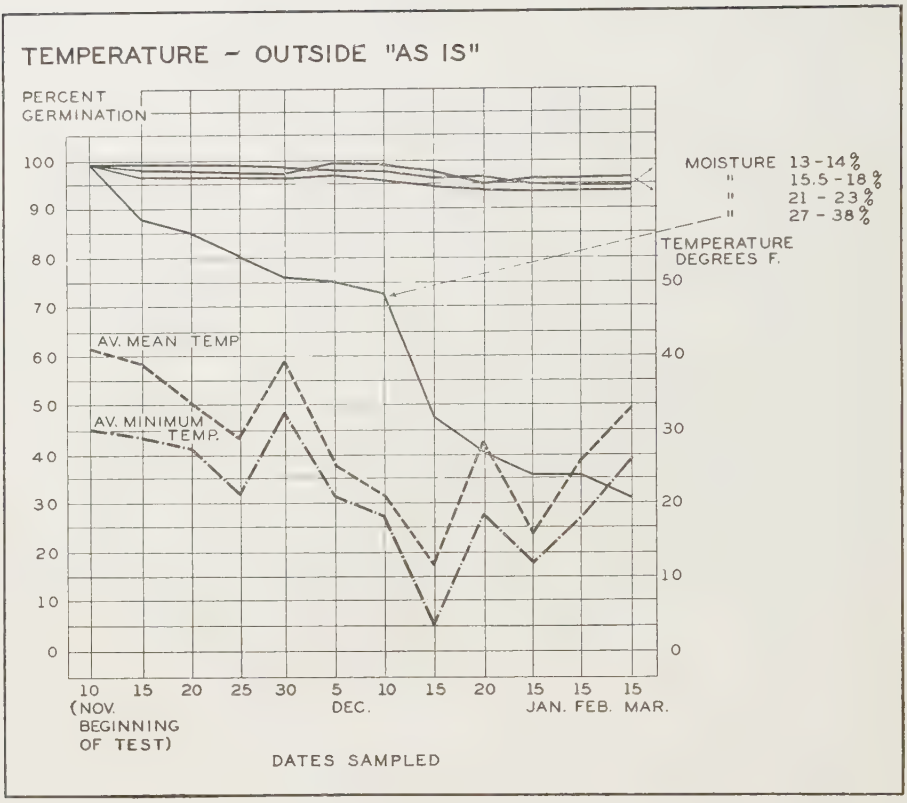


FIGURE 8

Figure 8 presents additional evidence that the high moisture group is seriously damaged by storage under average winter conditions. Even under the rather mild fall conditions that obtained at Guelph, appreciable damage to the germination of the corn was experienced. The much lower temperatures of late fall and early winter rendered the corn unfit for use as seed.

In the three tables included, the germination results of cobs of corn belonging to the three higher moisture groups are presented. The moisture content of each individual cob is recorded along with its germination at each temperature and period of storage.

TABLE 1.—GERMINATION OF COBS WITH 30% MOISTURE AND OVER AT DIFFERENT TEMPERATURES

| Temperature | Percentage moisture of cob | Percentage germination at end of period | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 5* | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 75 | 105 | 135 |
| −10° F. Fluctuating | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0° F. Steady | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0° F. Fluctuating | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15° F. Steady | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15° F. Fluctuating | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 35 | 5 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32° F. Steady | 32 | 95 | 90 | 90 | 90 | 92 | 91 | 90 | 95 | 90 | 89 | 90 |
| | 33 | 95 | 95 | 90 | 93 | 90 | 90 | 85 | 87 | 85 | 80 | 80 |
| | 37 | 95 | 90 | 90 | 85 | 85 | 50 | 40 | 20 | 15 | 12 | 15 |
| Outside "as is" | 30 | 95 | 90 | 65 | 60 | 60 | 40 | 5 | 5 | 0 | 0 | 0 |
| | 38 | 80 | 80 | 75 | 60 | 25 | 15 | 0 | 0 | 0 | 0 | 0 |

* Periods given in days.

The data presented in Table 1 indicate very clearly the damage that may be expected when corn with over 30% of moisture is exposed to temperatures of 15° F., and lower, even for very short periods of time.

TABLE 2.—GERMINATION OF COBS WITH 25% TO 30% MOISTURE AT DIFFERENT TEMPERATURES

| Temperature | Percentage moisture of cob | Percentage germination at end of period | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 5* | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 75 | 105 | 135 |
| −10° F. Continuous | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 26 | 25 | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| −10° F. Fluctuating | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0° F. Continuous | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0° F. Fluctuating | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15° F. Continuous | 28 | 85 | 85 | 85 | 75 | 65 | 65 | 55 | 60 | 60 | 55 | 60 |
| | 29 | 75 | 75 | 70 | 70 | 65 | 70 | 64 | 70 | 65 | 65 | 65 |
| 15° F. Fluctuating | 27 | 85 | 90 | 85 | 85 | 70 | 72 | 70 | 65 | 60 | 50 | 55 |
| | 27 | 80 | 55 | 55 | 50 | 60 | 55 | 50 | 40 | 35 | 25 | 25 |
| 32° F. Steady | 30 | 85 | 90 | 90 | 85 | 70 | 65 | 65 | 70 | 60 | 40 | 25 |
| | 28 | 100 | 95 | 95 | 100 | 100 | 95 | 95 | 100 | 95 | 95 | 95 |

* Periods given in days.

In Table 2 are presented data of the germination, at different periods, of corn with from 26 to 30% moisture exposed to 7 different conditions of temperature. In this instance, killing temperatures were around 0° F. even for short periods. At the higher temperatures varying amounts of damage were experienced.

TABLE 3.—GERMINATION OF COBS WITH 20.5% TO 25% MOISTURE AT DIFFERENT TEMPERATURES

| Temperature | Percentage moisture of cob | Percentage germination at end of period | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 5* | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 75 | 105 | 135 |
| −10° F. Continuous | 24.0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 22.0 | 10 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 20.5 | 10 | 10 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| −10° F. Fluctuating | 25.0 | 10 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 23.0 | 15 | 10 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 21.0 | 15 | 10 | 10 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0° F. Steady | 25.0 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 23.0 | 10 | 10 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 21.0 | 20 | 15 | 15 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0° F. Fluctuating | 25.0 | 10 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 24.0 | 15 | 10 | 5 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 0 |
| | 22.0 | 20 | 20 | 15 | 10 | 5 | 5 | 5 | 0 | 0 | 0 | 0 |
| 15° F. Steady | 25.0 | 75 | 60 | 65 | 60 | 65 | 65 | 55 | 60 | 50 | 55 | 55 |
| | 23.0 | 80 | 80 | 75 | 75 | 70 | 75 | 65 | 70 | 65 | 70 | 60 |
| 15° F. Fluctuating | 25.0 | 75 | 75 | 70 | 65 | 70 | 70 | 65 | 60 | 65 | 70 | 65 |
| | 21.0 | 85 | 85 | 70 | 75 | 75 | 80 | 70 | 70 | 75 | 70 | 70 |
| 32° F. Steady | 25.0 | 90 | 90 | 85 | 85 | 85 | 80 | 75 | 75 | 75 | 70 | 70 |
| | 24.0 | 85 | 85 | 85 | 80 | 80 | 75 | 85 | 75 | 80 | 75 | 70 |

* Periods given in days.

Table 3 presents similar data to that in Tables 1 and 2, but with cobs with initial moisture contents of from 20.5 to 25%. While complete destruction of the germinating ability of the corn was not experienced by short exposures at the lower temperatures very serious damage was evidenced with a temperature as high as 15° F.

## DISCUSSION

The evidence presented, on the whole, is in accord with the published findings of other workers on this particular problem. One might reasonably expect that a high percentage of moisture in stored corn would result in severe damage when such material was exposed to low temperatures. This is quite definitely indicated by the experimental evidence submitted.

An interesting feature of the data secured is the greater damage experienced when fluctuating rather than steady temperatures were employed. This is particularly evident in the lower moisture groups. This

appears to be in accord with the opinions of corn growers who report greater damage to germination from repeated drops in temperature than from a continuous cold period.

Considering the data as a whole, it would appear that corn stored with more than 20% moisture was very likely to suffer severely in its germinating ability in the event of any serious drop in temperature. Even with between 15 and 20% of moisture in the stored cobs, very appreciable lowering of germination was experienced. To be quite safe the moisture content of stored corn should be well below 15%.

Conflicting results which are secured at times from the material taken from individual cobs can very likely be explained by the observed differences in moisture content of corn taken from different sections of the cob. If a cob with high moisture content is stored without turning, the more exposed side dries out more rapidly than the protected area, thus causing a considerable difference in moisture in the two sections.

Both flint and dent varieties were used in the experiment, and no appreciable difference was obtained between the reactions of the two types.

## SUMMARY

A large number of ears of corn representative of 4 moisture groups were subjected to 8 conditions of temperature for varying periods of time.

The high moisture groups under all conditions of storage suffered severe damage to their germinating ability.

Fluctuating temperatures, particularly in the lower temperature groups, caused more damage than steady exposures to the lowest temperature concerned in each treatment.

No appreciable difference was recorded between the reaction of the dent and the flint corn types to any treatment.

For safe storage, the moisture content of corn should be well below 15%.

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BUROS, OSCAR K. (ed.). Research and Statistical Methodology Books and Reviews, 1933–1938. Rutgers University Press, New Brunswick, N.J., 1938. Pp. vi + 100. $1.25.

The continuous expansion in the output of scientific publications in recent years has led to a corresponding increase in the compilation of bibliographies. Confronted by the current proliferation of books and monographs in every branch of science, however, students, teachers and researchers may well have felt the need of some readily accessible information respecting the quality as well as the quantity of this output, which would assist them in minimizing unprofitable expenditures of time and money.

In these circumstances, the appearance of the work under notice, which provides information of this nature in connection with two specialties, "research methodology" and statistical methods, should be welcomed. The editor has assembled a list of 210 titles, which are arranged alphabetically according to author. The publisher, date and price of each are given, followed by excerpts from one or more (usually more) reviews in technical periodicals. In many cases the name or initials of the reviewer are also indicated. These will be found useful when the reader wishes to weigh the sometimes diametrically opposed opinions of different critics of the same publication, for it would seem that none of the works coming within Professor Buros' purview was so wholly bad that no one could be found to take up his pen in commendation of it.

It is stated in a prefatory footnote that "since the editor's special field of interest is in education and psychology, these fields are undoubtedly better represented than other fields." Whilst this would seem to be true of the "research methodology" section, the application of statistical methods to biology and agriculture on the other hand has been well covered. In this connection, moreover, the definition of a "book" adopted is sufficiently wide to include technical bulletins such as Brandt's *Tests of Significance in Reversal or Switchback Trials*, Geary and Pearson's *Tests of Normality*, Wishart and Sanders' *Principles and Practice of Field Experimentation*, Yates' *Design and Analysis of Factorial Experiments*, and the compilation by Roy and Mahalanobis of references on *Statistical Methods and their Application to Agronomy*, published by the Imperial Council of Agricultural Research, Delhi. There are two indexes of titles, one classified and one alphabetical, and an author index, which facilitate reference.

Except in the preface, a rather small type (judged to be 6-point) is used. This, however, is well-rounded, adequately spaced and quite legible. In fact, the general set-up of the volume is surprisingly good, in view of its moderate cost. It should find a useful place in the library of any teaching or research institution.

—J. W. HOPKINS.